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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

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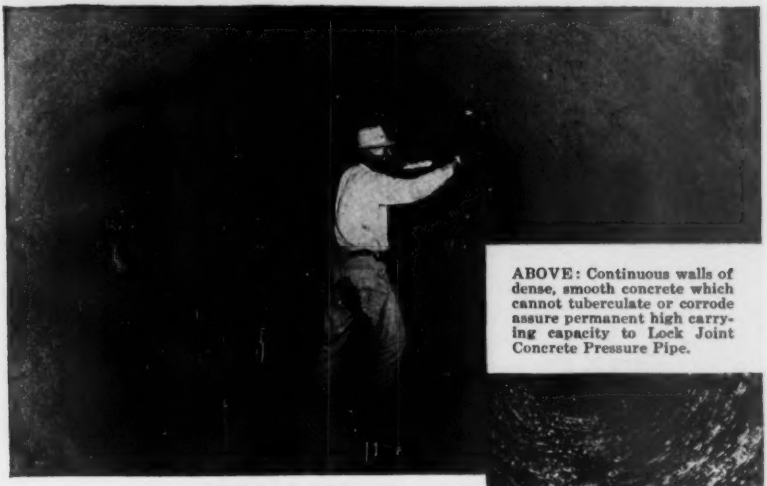

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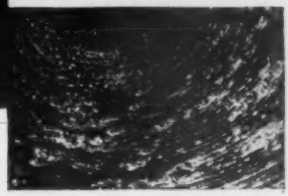

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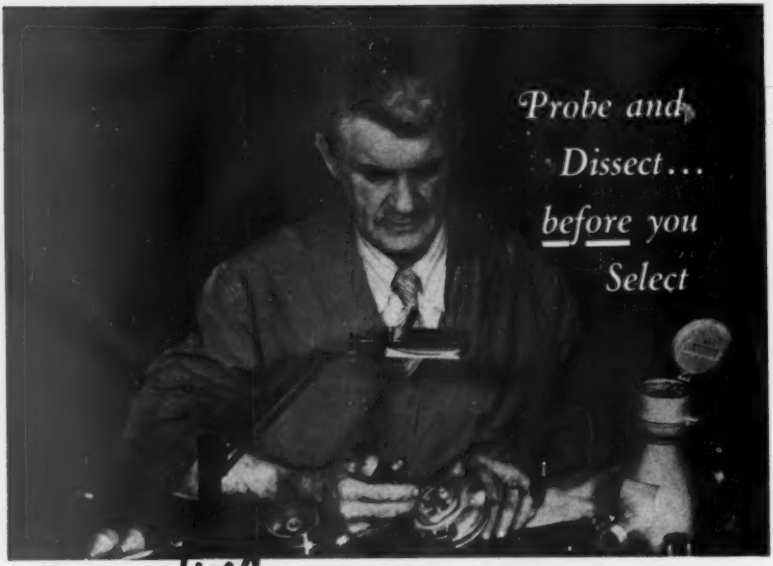

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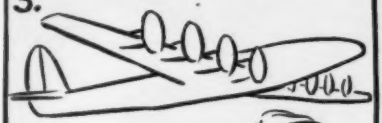

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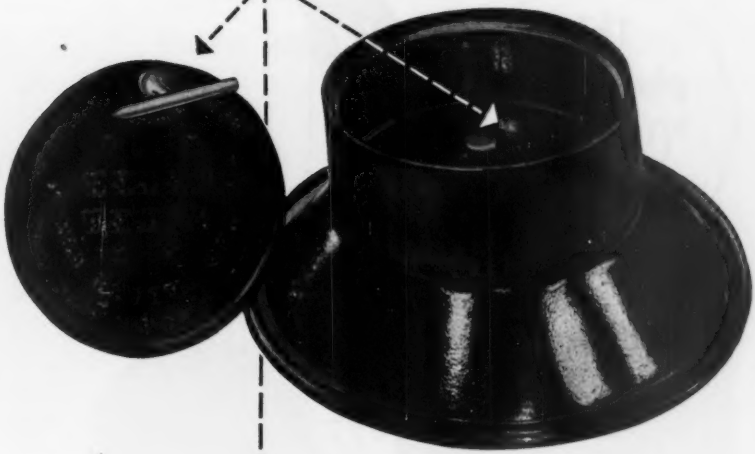

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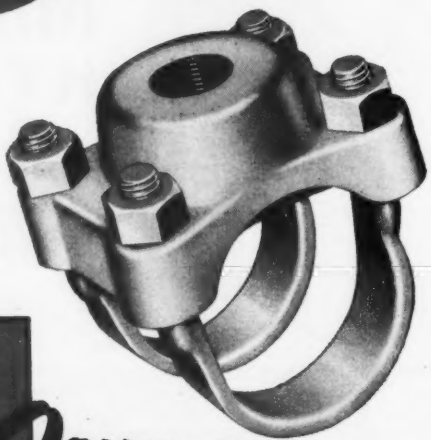

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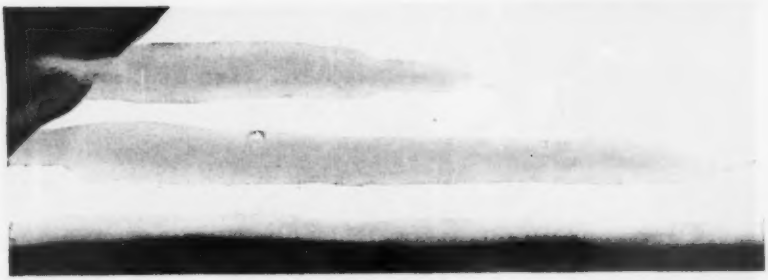

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*From THE WALL STREET JOURNAL, May 26, 1950

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ORGANIZED 1882

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This Association, as a body, is not responsible for the statements or opinions of any of its members

THE WATER-SUPPLY SITUATION IN NEW YORK CITY IN 1950

BY EDWARD J. CLARK*

[*Presented February 16, 1950.*]

YOU GENTLEMEN might ask, "How did New York City get into its present water difficulty; were their engineers negligent; didn't they have any foresight; were there no long-range plans in existence?" According to some of the letters we have been receiving, many people seem to think that we did not foresee the impending water crisis and had made no plans to forestall it.

I should like to assure you that such was not the case and that plans for the development of new sources of supply were prepared more than 20 years ago.

I don't know how well informed you are concerning the New York City water supply, but if the only information you have about it is what has been published in the newspapers during the past few months, you might be interested in the following facts. At the present time, the safe yield from all the sources of New York City's water supply is 1,015 mgd. This figure is based upon many years of record.

The consumption in New York City, including water supplied to communities outside the city limits, has been mounting by leaps and bounds in the last few years. In 1945 the consumption virtually reached the safe yield and since that date the former has exceeded the latter. Frankly, the only reason we were not in trouble from 1946 to the current shortage is that the rainfall and runoff were in excess of normal during these years. Last year the rainfall on the watersheds was more than 8 in. below normal and that deficiency, combined with high consumption, brought about the situation which exists today. In fact, during the past summer we saw what was coming. Our reservoirs were

*Chief Engineer, Bureau of Water Supply, Dept. of Water Supply, Gas and Electricity, Municipal Bldg., New York 7, N. Y.

full and spilling on the 28th day of May of last year. The normal condition is for the reservoirs to be full on or about June 1st, when the draw-down usually begins. The dry spell set in about that date and continued for several months. This, coupled with the high consumption, brought about a situation which was very different from the usual condition of late September. We then appealed to the public, requesting them to conserve on the use of water. As the dry spell continued, the publicity campaign for the conservation of water was increased.

In October the conservation drive was intensified through the media of the press, radio and television. The period of October 2-8 was taken as a base week and the average daily consumption during this week was ascertained to be 1,192 mil gal. Subsequent to that week the consumption dropped, due to the splendid coöperation brought about through the publicity agencies, and the reduction in consumption until about three weeks ago has been increasing practically each week. For the past ten weeks or so the use of water has been about 300 mgd less than during the base week. I think that is a remarkable tribute of coöperation on the part of the people of the city.

Two weeks ago, a low consumption of 860 mgd was reached. Compare this with the base-week figure of 1,192 mgd and a saving of 332 mgd will be noted.

The reasons for the high consumption are several. The population of New York City has increased; commercial and industrial uses of water have also increased. The air-conditioning and refrigeration industries have expanded beyond anticipated limits. At the inception of the air-conditioning and refrigeration industries the city promulgated regulations, governing the use of water by air-conditioning and refrigeration units, which did not require any unit less than 25 tons to recirculate. However, due to the present water emergency, we had to revise these rules so that at the present time any unit over three tons must recirculate. Although the Commissioner has no authority to make the rules retroactive, he has, however, the power to determine what is a wastage of water, and he has indicated that if the drought continues through the spring months, he will consider the water consumed by non-recirculating air-conditioning and re-

frigeration units as a wastage of water and will have them shut down. On the basis of this declaration many existing non-recirculating plants are converting to recirculating ones.

Some people are under a misapprehension as to the functions of the Department of Water Supply, Gas and Electricity. There are two separate and distinct agencies in the city of New York. One is the Board of Water Supply and the other is the Department of Water Supply, Gas and Electricity. The Board of Water Supply was created to make studies of future water needs, to secure additional sources of water supply for the city of New York and to develop these sources, such development including all construction work. In other words, they build all the dams, all the facilities in up-state New York, and when these facilities are constructed, they are turned over to us (Dept. of Water Supply, Gas and Electricity) for operation and maintenance.

In 1927 the Board of Water Supply made plans for the development of the Delaware system, but since it included the watershed areas of some of the tributaries of the Delaware River, which runs through New Jersey and Pennsylvania, there was litigation for several years, so that it was not until several years later that the United States Supreme Court permitted the city of New York to take water from these areas. About the time the United States Supreme Court gave us a favorable decision we were in the midst of a depression, with no funds available for construction purposes. During the depression years business declined, with a resulting decrease in consumption, and, as the city had no funds, the development of the Delaware system was delayed.

In 1937 the Board of Water Supply began actual construction of the Delaware system. When World War II started all construction stopped. When the war was over there was a shortage of materials and supplies. Because of these factors the completion of the Delaware system has been delayed about six or seven years. If it had not been for the war, this system would have been ready several years ago.

That Delaware water system is being constructed in two different stages—two separate water steps. The first comprises the Rondout and Neversink supplies and the second the East Branch of the Delaware River. The Rondout supply will be completed early

next year. In two or three years the Neversink supply will be available and in another five years the East Branch of the Delaware will be completed. These additional supplies will augment the present dependable supply of 1,015 mgd by 505 mgd, to make a total of 1,520 mgd.

From present indications, I think we are going to conquer the water shortage. The greatest single factor that will help to do this is the daily conservation on the part of the people of New York City. It is quite difficult to make the people change their regular water habits and to conserve water. I must express my thanks to the newspapers, the radio and television for the publicity which they have given us. They have been remarkably expert in handling it and that is the prime reason why the people have conserved over 300 mgd. It has been a difficult job and it will become more difficult if the 300-mgd saving is to continue.

Should conditions grow worse, the Board of Water Supply is going to tap the Hudson River as an emergency source of water supply. The plan is to take 100 mgd from the Hudson River at Chelsea, N. Y., which is about 65 miles up the Hudson River from New York City. The Delaware aqueduct crosses the Hudson River at this point and it is planned to pump the water from the river into the aqueduct against a head of approximately 600 ft. Although the water is polluted, it will be rendered potable by superchlorination at the source, passage through two storage reservoirs where it will receive sedimentation, chlorination at each of the effluent chambers of these reservoirs and, finally, chlorination at the effluent chamber of the distribution reservoir at the city line. The water from the Hudson River will be used only in an extreme emergency, if all of our other sources of supply when used to their maximum capacity fail to meet the demands in the city. I hope such a state will never arise.

To increase further the dependable supply after the second stage of the Delaware is completed, the Board of Water Supply has recommended to the Board of Estimate the development of a third stage of the Delaware watershed by impounding the waters of the West Branch of the Delaware River, which will yield 323 mgd. Before this can be done, permission must first be obtained from the State Water Power and Control Commission and then from the United States Supreme Court.

In addition to the above and on a long-range basis, a tri-state organization, Incodel, composed of New Jersey, Pennsylvania and New York, has been created, to formulate an over-all plan for a system which will take care of the three states—that is, the city of New York and the various cities in the states of Pennsylvania and New Jersey. This is to be developed on a vast scale. Thus, you can see that the city officials are looking into the future, much beyond anything that may exist today.

When a water shortage, such as the current one, is experienced, many suggestions to cope with it are offered. One of these, that has been proposed on numerous occasions for the past 50 years, is metering.

At the present time the city of New York is practically unmetered. There are no regulations requiring that the domestic use of water be metered. Commercial and industrial uses are metered, but they constitute only about 27% of New York City's water supply. Commissioner Carney of our Department expects to introduce a bill in the Board of Estimate, within the next week or two, to meter all multiple-family apartment houses in the city of New York. It is difficult to estimate the amount of water that would be saved by this type of metering. Some of the water-works engineers think it would be considerable. I, for one, will not predict the savings to be effected in this way, because there are not enough data available upon which to base a fair estimate.

We can't institute universal metering at the present time. The job is so vast that it would swamp the meter industry if we tried to do it all at once. Also it would have a very disturbing effect on the various real-estate owners and landlords in the city, who are opposed to it. They seem to think that, in addition to the initial installation cost, their water bills would be increased.

Several newspapers, in the past month or so, have been saying that scientists claim that with $20 worth of silver iodide we can get all the rain we want. Yesterday, Commissioner Carney and I went to see Dr. Langmuir and some of his assistants at the General Electric Co. in Schenectady, N. Y., to confer with them on this matter. We saw some of the experiments that they have been making for several years. They claim to have made very successful experiments in New Mexico and Arizona, and it is thought that the same

results might be achieved in New York. However, there are many differences between the areas supplying water to New York City and the areas of experiment in New Mexico and Arizona comprising about 120,000 sq mi. That is a vast area and there is nothing there. We have three watersheds up-state and there are, on the average, about 300 sq mi in each. We do not own the watersheds. We own the reservoirs and marginal strips, but the vast areas in the watersheds are privately owned and just what the reaction of the owners would be, if we caused extra rainfall, we do not know. I am thinking of possible litigation. In fact, the General Electric stopped their experiments, because they suddenly realized that their experiments might bring on litigation which would keep their entire legal staff busy for generations to come. You can't answer the question, "Who owns the clouds?" Or, if you own a farm, how far down do you own it, and how far up? If we saw a cloud and took the water out of it, maybe we should be taking it away from Massachusetts, away from Boston. If we take it in up-state New York—maybe it would have gone to Canada if we had not taken it. That may sound facetious, but you can see that artificially stimulating the clouds might lead to international disputes.

Furthermore, we have spoken to several people who have been carrying on cloud-stimulation experiments in the vicinity of California and New Mexico, and they are frank to admit, "We have not found out yet," as concerns the conclusion to be drawn from these experiments. The Weather Bureau, the United States Army Signal Corps, the G. E. experimenters and private experimenters all seem doubtful as to what they can do.

Many scientists claim that rain cannot be precipitated unless there is natural rain within 30 miles. They also claim that a natural rainfall can be made to stop, depending upon the amount of seeding that is done.

Thus, it becomes apparent that "rain-making" is a very controversial matter and the city of New York, before it does anything along this line, will be sure that it is absolutely protected in the course it will pursue.

Our consumption varies greatly from one day of the week to another. On Monday the consumption is high, and it tapers down

at the end of the week. The newspapers were really responsible for what we were able to accomplish in regard to the shaveless and bathless days. The newspaper reporters go around on the dry days and inquire of any man who has a clean face as to why he is shaved. It was found that apparently 99% of the men either lived in New Jersey or had electric razors. That is the way it has turned out. Unluckily, I had to address an affair at the Waldorf Astoria on two, successive dry Thursdays and I did not dare to shave, because I knew there would be a photographer taking pictures and, if they took a picture of me with a clean-shaven face, they would "hang" me.

On the 12th of December our storage capacity declined to an all-time low, with a little over 84.5 billion gallons of water or 33.4% of capacity. When full, the reservoirs hold 253 billion gallons. Since that date the reservoirs have been gradually filling up, so that at present there are about 116 billion gallons of water in storage or about 46% of capacity. The heavy rains of the last few days contributed greatly to the increase in storage. A year ago the storage was over 83% of capacity. On June 1, 1949, the reservoirs were full, and look where they are today! It is estimated that, with normal rainfall of 14-1/2 in. between now and the first of June, and also on the assumption that the consumption will remain at its present low level, which is very improbable, the reservoirs will be only three-quarters full. June 1, as you know, is the beginning of the drawdown period. In order to make the reservoirs full on that date, if we assume that the consumption will be kept at its present low rate, 19 in. of rainfall would be required. This is improbable and thus you can appreciate the problems that confront us.

So that a water famine may be averted in the future, we must continue to conduct the conservation campaign with the same vigor as in the past. I want to take this opportunity to thank the people of the city of New York for their unprecedented coöperation in reducing their water use to a minimum and thus effecting a saving of over 300 mgd.

I don't think I should have come here and apologized for being short-sighted. The city of New York has taken all the blame, but I believe that some of it can be placed here. As already mentioned, the Board of Water Supply is the agency which is responsible for

securing additional water supplies for the city of New York. On the staff of this Board is a very famous consulting engineer from Boston, Mr. Frank Marston. Take some of the blame, Frank! (*Laughter*) But seriously, we have what is called the interdepartmental board in New York City and Frank is a member of this board. It is really a very fine working organization. I want to pay public tribute here today, Mr. President, to Frank Marston, because we are guided to a great degree by the suggestions and recommendations which he makes.

TECHNICAL INVESTIGATIONS OF ADDITIONAL GROUND-WATER SUPPLIES IN RHODE ISLAND*

BY WILLIAM B. ALLEN**

[*Read April 20, 1950.*]

THE economic value of the ground-water resources of Rhode Island has long been recognized, but the importance of efficiently developing and conserving this supply has not been as fully recognized. Only within the past few years has the need for a comprehensive survey of ground-water conditions become apparent.

Realizing the need for study of the State's ground-water problems, the Rhode Island Industrial Commission in 1944 entered into an agreement with the Geological Survey, U. S. Department of the Interior, to conduct a coöperatively financed investigation of the ground-water resources of Rhode Island. This study is a part of a larger coöperative program that also involves geologic investigations. In October, 1945, the writer was assigned to this project, which is continuing at the present time. The program is under the general direction of E. S. Woodmancy, Executive Secretary, Rhode Island Port and Industrial Development Commission, and M. L. Brashears, Jr., District Geologist, Ground Water Branch, U. S. Geological Survey.

The purpose of the ground-water studies is to obtain detailed information concerning the occurrence and availability of ground water in the State, to ascertain the areas capable of supplying large quantities of water for industrial development, and to determine the quantity and quality of water available from each aquifer in such areas. Because the funds available for the investigation are relatively small, only a small part of the State can be covered each year. It is planned, therefore, to continue the work from year to year until the entire State has been covered.

The field work that forms the basis of such a study consists

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chiefly of an inventory of existing wells and the collection of related information pertaining to ground-water conditions. Many of the well data are obtained from statements and records of well owners, and well logs are furnished by well drillers. Measurements of ground-water levels and observations of ground-water conditions are made at the time each well is visited. Officials of public water-supply systems utilizing ground water and private well owners, both industrial and domestic, are interviewed. In each area covered, many of the domestic wells and all the wells that are known to yield considerable quantities of water are visited. The well records collected, in addition to the well logs and measurements of ground-water levels, include data pertaining to well construction, water-bearing formation, depth to bedrock, depth and yield of well, and related information. The location of each well is plotted on a topographic map at the time the well is visited.

At the start of the program it was considered advisable to use the new, U. S. Geological Survey, 7½-minute topographic sheets as the basic unit for field mapping and to publish reports of areas covered by them as they were studied. Reports have been completed and published for the city of Providence, the Pawtucket quadrangle, and the city of Woonsocket. A report covering the Georgiaville quadrangle will be printed within a few months. Field work has been completed in the East Greenwich quadrangle and started in the Bristol quadrangle.

Intensive local studies have been completed in several other critical areas, such as in north-central Cranston, the Goddard Memorial Park in Warwick, Davisville in North Kingstown, Exeter School in Exeter, Mashapaug Pond in Providence, Tuckertown in South Kingstown, and in Bristol County, to assist in the solution of various water-supply problems connected with public, industrial, State and Federal establishments. The location of these areas is shown in Figure 1.

Measurements of ground-water level are being made in about 75 observation wells throughout the State, for the purpose of determining natural water-table conditions and the relation between ground-water levels and pumping. These data are published annually in water-supply papers of the Geological Survey. Records not yet

MAP OF
THE STATE OF
RHODE ISLAND
SHOWING
LOCATION OF AREA COVERED BY THIS REPORT
AND OTHER AREAS WHERE GROUND-WATER
CONDITIONS HAVE BEEN INVESTIGATED.
LEGEND
1. DAVISVILLE REPORT
2. PROVIDENCE PROGRESS REPORT
3. GODDARD PARK REPORT
4. PAWTUCKET QUADRANGLE
5. MASHAPAUG REPORT
6. EXETER REPORT
7. CRANSTON STUDY
8. GEORGIAVILLE QUADRANGLE
9. WOONSOCKET REPORT
10. TUCKERTOWN STUDY
11. BRISTOL COUNTY REPORT
12. EAST GREENWICH QUADRANGLE
13. BRISTOL QUADRANGLE
MASSACHUSETTS
BURRILLVILLE
NORTH SMITHFIELD
SMITHFIELD
LINCOLN
CUMBERLAND
CITY OF CENTRAL FALLS
GLOCESTER
PROVIDENCE COUNTY
NORTH PROVIDENCE
CITY OF PROVIDENCE
EAST PROVIDENCE
JOHNSTON
FOSTER
SCITUATE
CITY OF CRANSTON
CONNECTICUT
CITY OF WARWICK
COVENTRY
KENT COUNTY
WEST GREENWICH
EAST GREENWICH
BRISTOL
TIVERTON
EXETER
NORTH KINGSTOWN
NARRAGANSETT BAY
NEWPORT
PORTSMOUTH
MIDDLE-TOWN
LITTLE COMPTON
WASHINGTON COUNTY
RICHMOND
JAMESTOWN
NEWPORT
CITY OF NEWPORT
HOPKINTON
SOUTH KINGSTOWN
NARRAGANSETT
OCEAN
CHARLESTOWN
WESTERLY
ATLANTIC
OCEAN
BLOCK ISLAND
NEW SHOREHAM

FIGURE 1.

published may be consulted at the office of the Geological Survey in the Custom House Building, Providence. Before continuing further studies in Rhode Island, a State-wide reconnaissance report is being prepared as a basis for planning future detailed and systematic investigations.

Many of the present users of ground water are confronted with the problem of obtaining larger quantities of water, or water of more desirable quality. In some localities ground water is needed to supplement surface water, particularly during periods of low stream flow. The manner in which the Geological Survey has aided in the search for additional water supply is illustrated in the following statements.

During the war, the United States Navy requested the Geological Survey to study the ground-water supply of the Naval Advance Base Depot at Davisville and to report on the cause of declining pumping levels in wells. A hydrologic study showed that static and pumping water levels fluctuated widely with the high and low stages of the nearby Hunt River. Supply wells were found to be underequipped for pumping at their useful capacity. Upon recommendation of the Geological Survey, pump capacities were increased and pump columns were lengthened. This proved to be a satisfactory solution to the problem.

As part of the 1945 program of ground-water investigations, a well inventory was made at Potowomut in Warwick for the State Division of Forests, Parks, and Parkways, for the purpose of determining the availability of ground-water supplies at Goddard Memorial Park. In a report furnished the State it was suggested that wells could be drilled in certain favorable areas to obtain a required supply of about 225 gallons a minute.

At the request of the Rhode Island Commission on Coördination and Execution of Postwar Programs, a brief investigation was made to determine local ground-water conditions at the Exeter School, a State institution for the mentally deficient. In order to alleviate the considerable hardship caused by water shortages and to provide fire protection, the water-supply facilities had to be expanded immediately. Field reconnaissance indicated that moderate supplies of ground water could be developed from the glacial drift. Under the supervision of consulting engineers, test drilling was undertaken and

supply wells were constructed at two of the favorable locations. Three years after installation these wells are still yielding a satisfactory and reliable supply.

In order to obtain additional ground-water data in the southern part of the State and to aid consulting engineers in the development of a public water supply, hydrologic studies were made at supply wells of the Wakefield Water Co. at Tuckertown, South Kingstown. Data obtained from an automatic water-stage recorder, installed by the Geological Survey, has indicated the probable maximum yields to be expected under adverse conditions of operation. With this water-level information available, consulting engineers were able to plan their water-conservation program and determine their most economical plant operation.

The prolonged drought in the summer and fall of 1949 had an important effect on many public water supplies. During this period the surface-water supplies in Pawtucket and in the Bristol County area proved inadequate to the demand. East Providence, although not actually short of water, decided to locate a supplementary supply of better quality. The Geological Survey had made no ground-water investigations in this area, and it was therefore necessary for consulting engineers to locate their underground reservoir by means of seismic exploration and test drilling. Extensive testing indicated that a supply of about 3 mgd was available in the vicinity of the East Providence Reservoir. It is expected that supply wells will be drilled in the near future.

Pawtucket, with the aid of consulting engineers, who used the U. S. Geological Survey ground-water map of the Pawtucket quadrangle as a basis of information, conducted a test-drilling program, which located ground-water supplies from which about 6 mgd could be pumped.

Because of the urgent need for additional water supplies in the towns of Bristol, Warren and Barrington, the Rhode Island Port and Industrial Development Commission requested the Geological Survey to make an investigation of the ground-water conditions in Bristol County and to prepare a report, based on the results of the study. The investigation was made as part of the State-wide study of the geology and ground-water resources of Rhode Island.

Field work forming the basis of the report consisted of a well inventory, preliminary study of surficial glacial deposits, and collection of other related data. The report indicated that only small scattered supplies of ground water could be obtained from the glacial drift in Bristol and Warren, but that the stratified drift in Barrington could be expected to yield moderate supplies of ground water to properly constructed wells. The best area for development was indicated to be between the Barrington River on the east and the Providence River on the west, even though subsurface information was limited and somewhat conflicting. An ice company had obtained an abundant supply, whereas wells drilled for an old brick company had produced little or no water. However, the Bristol Water Co., which supplies water to the towns of Bristol, Warren and Barrington, decided to carry out a test-drilling program in Barrington between the Providence River and the next inlet to the east. Test wells were first drilled in the vicinity of the ice company, but no water was obtained. A gravel pit was next explored, but again without success. Test drilling was then conducted within a short distance of the brick company. This location proved to be more favorable and a well, constructed last fall during the drought, yielded 800,000 gallons a day. A second well is under construction, and it is proposed to use these two wells to supplement the present surface-water supply for the three towns.

A detailed geologic and ground-water survey of the Bristol quadrangle has been started. It will result in a report, describing the geology and ground-water resources of the area with maps showing the glacial deposits, the bedrock formations, and ground-water data.

Additional ground-water studies are to be made in Rhode Island. These studies will doubtless indicate areas where additional ground-water developments can be made and perhaps a few areas where present developments are already excessive.

PEAK DEMAND LOADS IN WATER-SUPPLY SYSTEMS

BY WILLIAM E. STANLEY*

[*Read September 18, 1950.*]

THE term "peak demand loads," assigned this paper by your ingenious program chairman, has not been as commonly used in the water-supply utility field as in other utility fields. The use has been partially acknowledged in "Glossary—Water and Sewage Control Engineering" (APHA, ASCE, AWWA, FSWA). More extended use may be expected in the future, as more rate schedules come into vogue with rates of charge based on "peak demand loads." Otherwise there may be confusion between peak *rates* of water usage and *rates* of charge for peak demand loads in the water-supply system.

As an illustration, Kansas City, Mo. (1), has adopted a zone and peak demand rate of charge in its water-service rate schedule, which takes into account the distance through which the water must be conveyed and also the peak demand flow. Thus, certain water users are encouraged to install water storage on their premises.

Illustrative data on peak demand loads in three water supply systems (Quincy, Taunton and Belmont) are recorded in this paper, taken largely from four student theses, presented to Massachusetts Institute of Technology in partial fulfillment of degree requirements. These were by Messrs. H. V. Patterson (2), Manuel Vinas-Sorba (3), Chia-Tsun Hu (4), and Edward J. Ewing (5). These studies were made possible through the interest, assistance and courtesy of Messrs. Arthur Harrington, John G. Whitman, Arthur C. King, and Walter G. Conroy.

Water-System Characteristics

The three water-supply systems—Quincy, Taunton and Belmont—all in Massachusetts, have differences in character of community, physical characteristics, and in operating procedures, which materially affect peak demand loads supplied by the three water systems.

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Quincy and Taunton have had substantial industrial water requirements, while Belmont is entirely a residential town. Quincy and Belmont receive their water supply from the Metropolitan District Commission through recording meters. Belmont has no storage, while Quincy has substantial storage (Table 1), much of which was not effective during the period of the studies.

TABLE 1.—DISTRIBUTION-SYSTEM STORAGE, QUINCY, MASS.

Reservoir	Volume capacity (gallons)	Elevation
Forbes Hill	5,100,000[1]	192
Forbes Hill*	333,000	251
Cranch Hill*	2,000,000	233.5
Penn Hill*	1,000,000	233.5
Penn Hill†	200,000	256
Hough's Neck*	400,000[2]	205
Squantum*	300,000[2]	211
Break Neck Hill†	197,000	269
Total	9,530,000	

*Standpipes.
†Booster standpipes.
[1]Too low for best service.
[2]Kept full at all times.

Taunton has had direct pumpage with no distribution storage and also has followed the practice of increasing pumping discharge pressures from a routine pressure of 70 psi to a fire pressure of 100 psi at each fire alarm—1,780 times in the 10-year period studied: 1935-1944.

Yearly Average Water Demand

A base average water demand may be easily computed and easily verified by dividing the total annual recorded water volume supplied to all water users by 365 (or 366) days, to give the yearly average daily demand or load on the water-supply system. Maximum and peak water demand loads may be, and frequently have been, expressed as percentages of the yearly average daily demand.

The yearly average daily water demand for the years covered by the records studied were as follows:

Community	Year	Population	Yearly average daily water demand	
			M.G.D.	Gallons per capita
Quincy	1940	73,000	4.92	67
Taunton	1944	39,000	4.06	104
Belmont	1946	29,300	2.02	69

The prewar records for Quincy were studied, advisedly, because of numerous disturbing uncertainties in the wartime records and unusual variations in water quantities needed by certain industries.

The Taunton 1944 water demands were higher than during prewar years, due to substantial increases in water used by industries (Figure 1). The Taunton Water Department records have shown the yearly total water demand divided between domestic and commercial-industrial accounts since 1885, an excellent long-time record.

Belmont yearly average daily water demand has steadily increased with population increase from 1905 to 1946 (Figure 2). The yearly average per-capita daily demand has ranged from 54 to 69 gal (up to 73 in 1949).

The proportion of the yearly total water demand accounted for by records of metered consumption (Table 2) is often considered as an index of efficiency of water-system operation. It may be an index of the accuracy of the master water meter. From 1935 to 1944 the unaccounted-for water decreased to 19% in Taunton, but increased from 17% to nearly 20% in Belmont; by 1946 it was nearly 31% in Belmont (26% in 1949).

This difference in the trends of the percentage of unaccounted-for water in Taunton and in Belmont may be partially explained by the nature of the increases in water consumption. In Taunton the industrial consumption, all metered, increased with the years, whereas the lineal feet of pipe, hence possible leaks, remained substantially the same—so possibly the unaccounted-for leakage remained substantially the same, hence the percentage rate decreased. In Belmont there were no similar large increases in large metered industrial consumption, so the increase in water use due to increased population followed the trend of higher per-capita and higher losses with popula-

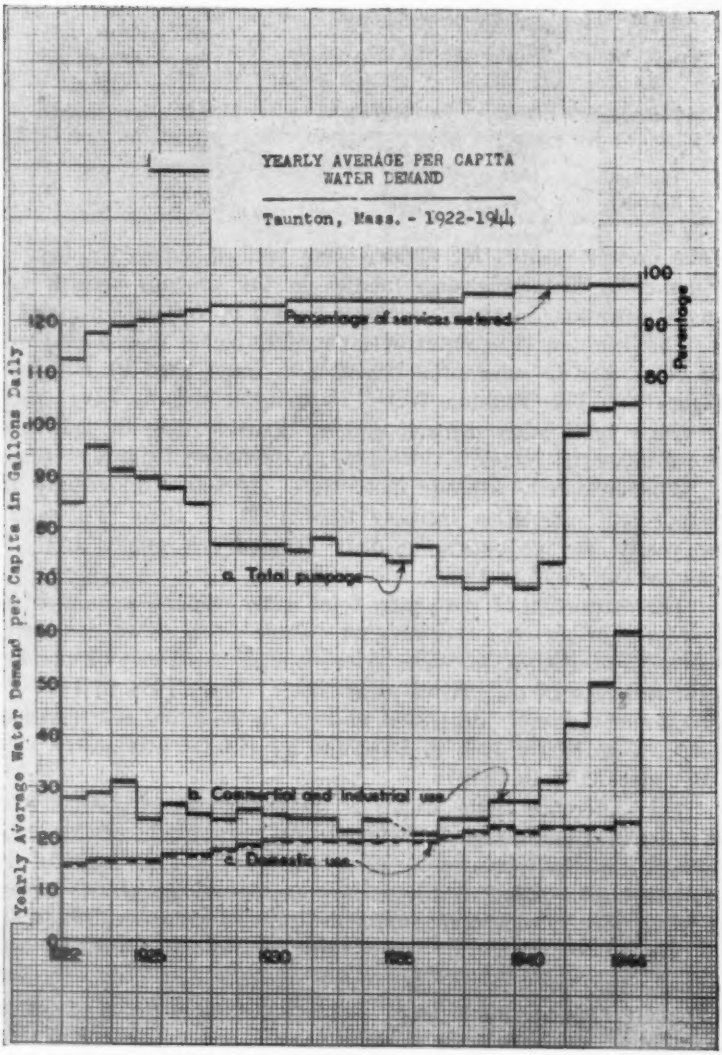

YEARLY AVERAGE PER CAPITA
WATER DEMAND
Taunton, Mass. - 1922-1944
Yearly Average Water Demand per Capita in Gallons Daily
Percentage
Percentage of services metered
a. Total pumpage
b. Commercial and industrial use
c. Domestic use
120
110
100
90
80
70
60
50
40
30
20
10
0
100
90
80

FIG. 1.

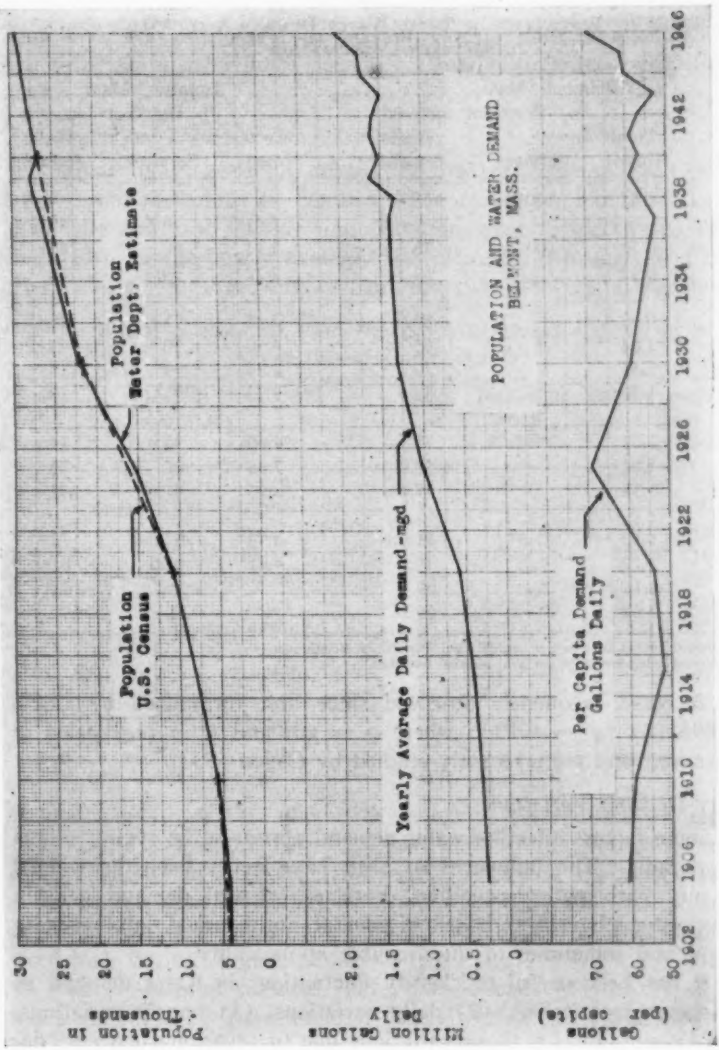

POPULATION AND WATER DEMAND
BELMONT, MASS.
Population
Water Dept. Estimate
Population
U.S. Census
Yearly Average Daily Demand-mgd
Per Capita Demand
Gallons Daily
Population in Thousands
Million Gallons Daily
Gallons (per capita)
30
25
20
15
10
5
0
2.0
1.5
1.0
0.5
0
70
60
50
1902
1906
1910
1914
1918
1922
1926
1930
1934
1938
1942
1946
Years

FIG. 2.

TABLE 2.—PERCENTAGE OF TOTAL WATER DEMAND ACCOUNTED FOR BY METERED CONSUMPTION

	Belmont, Mass.			Taunton, Mass.		
		Per cent metered			Per cent metered	
Year	Total (mgd)	Services	Water demand*	Total (mgd)	Services	Water demand†
1905	0.27	100%	58%	—	—	—
1906	—	—	—	1.91	46%	41%
1910	0.33	100	58.5	2.15	50	46
1915	0.43	"	82.5	2.22	59.5	56
1920	0.59	"	86.9	3.40	71	48
1925	1.05	"	65	3.50	90	45
1930	1.31	"	79	2.86	93	58
1935	1.37	"	83.5	2.73	93	59
1940	1.52	"	79.7	2.60	96.9	74
1941	1.63	"	77.9	2.88	97	74
1942	1.58	"	77.1	3.75	97.6	68
1943	1.50	"	81.9	3.94	97.6	72
1944	1.72	"	79.9	4.01	97.6	81
1945	1.76	"	69.4			
1946	2.02	"	69.2			

*Metered consumption as per cent of total demand by M.D.C. meters.
†Metered consumption as per cent of total pumpage.

tion increase, frequently observed since first formulized by Coffin in 1896 (6) [$q = 40P^{0.14}$, where q = gcd and P = population in thousands] and more recently studied by Capen (7).

Water-Demand Variations

Some factors affecting water demand appear to be cyclic; others are sporadic. The influences of each have never been determined with any mathematical precision. Forecasts of peak demand loads in water systems have been based, in general, on historical data—usually meager and sometimes of questionable applicability.

It has been useful to classify fluctuations in water demand as (1) seasonal variations, (2) daily variations, (3) hourly variations, and (4) sporadic, *i.e.* those variations due to occasional extreme demand load which occur with no regularity. These are not new des-

ignations, but are useful to present certain data supplemental to the relatively meager items presently available in water-supply literature.

Seasonal Peak-Demand-Load Variations

Monthly average daily demand figures are the more usual indices of seasonal variations in demand. The maximum monthly average daily demands for Quincy and Taunton were, respectively, 110% and 123% of the yearly average daily demand. An analysis (Table 3) of eleven years' records at Taunton, 1934-1944 inclusive, showed

TABLE 3.—SEASONAL PEAK DEMAND LOAD, TAUNTON, MASS.*
(From 1934-1944, incl., records)

Year	Month	Maximum monthly average daily demand load	
		M. G. D.	Percentage†
1934	August	3.04	109.0
1935	August	2.98	109.0
1936	June	3.25	114.0
1937	July	3.01	114.5
1938	August	2.88	112.4
1939	August	2.92	111.0
1940	November	2.89	111.5
1941	August	3.10	110.0
1942	December	4.53	121.0
1943	July	4.44	112.5
1944	August	5.00	123.1

*Based on "Water Supply Demand Fluctuations" by Manuel Vinas-Sorba (M.I.T. thesis, 1945).
†Percentage of yearly average daily demand for each year.

August, 1944, as the maximum monthly average daily demand (123%). The maximum demand load in the water system occurred during summer in all except two years—1940 and 1942. A detailed study (4) of water-consumption records indicated that both domestic peak demand loads (lawn sprinkling?) and industrial peak demands were high during August, 1944.

The residential seasonal peak demand loads (Figure 3) in Belmont were a higher percentage of yearly average daily demands than in the industrial cities of Quincy and Taunton. Data for each of the four M.D.C. meters were as follows:

Meter	Max. monthly aver. monthly demand load M. G. D.	Per cent of yearly aver.	Pressure district in Belmont
#62	0.62	142.4	High pressure
#88	0.73	141.5	Low pressure
#110	0.93	120.1	Intermediate pressure
#111	0.06	189.5*	Intermediate pressure (small)
All meters	1.98	136.4 aver.	

*A leak may have caused such high rate.
Weekly average maximum demand in Belmont reached 163% of the yearly average during July, 1943 (Figure 4).

These records show that seasonal peak demand loads in these three water-supply systems have been during the summer, with few exceptions. Other communities with more severe winters may find heavy seasonal demands during winter months.

Daily Variations in Peak Demand

Data on daily variations are not easy to collect and more difficult to place on a mathematical probability basis. Relatively few such data are found in literature, based on reliable records.

The frequent increases in pumping pressure during fires made much of the Taunton data on daily variations unsatisfactory. Two weeks' records—one in summer and one in winter—were found relatively free of fire-pressure disturbances. These data have been graphically recorded (Figure 5). They show water demand for Sundays as substantially lower than week days, and water demand for Saturdays to be intermediate between Sundays and other week days. Hu arranged the Taunton data by week days (Table 4) and also determined the maximum, the average and the minimum daily demand for each week day (Figure 6). No statistical analysis was prepared.

Hourly Variations in Demand Loads

Patterns of charts illustrating hourly variations in water demand are similar with respect to the hours of low demand and hours of

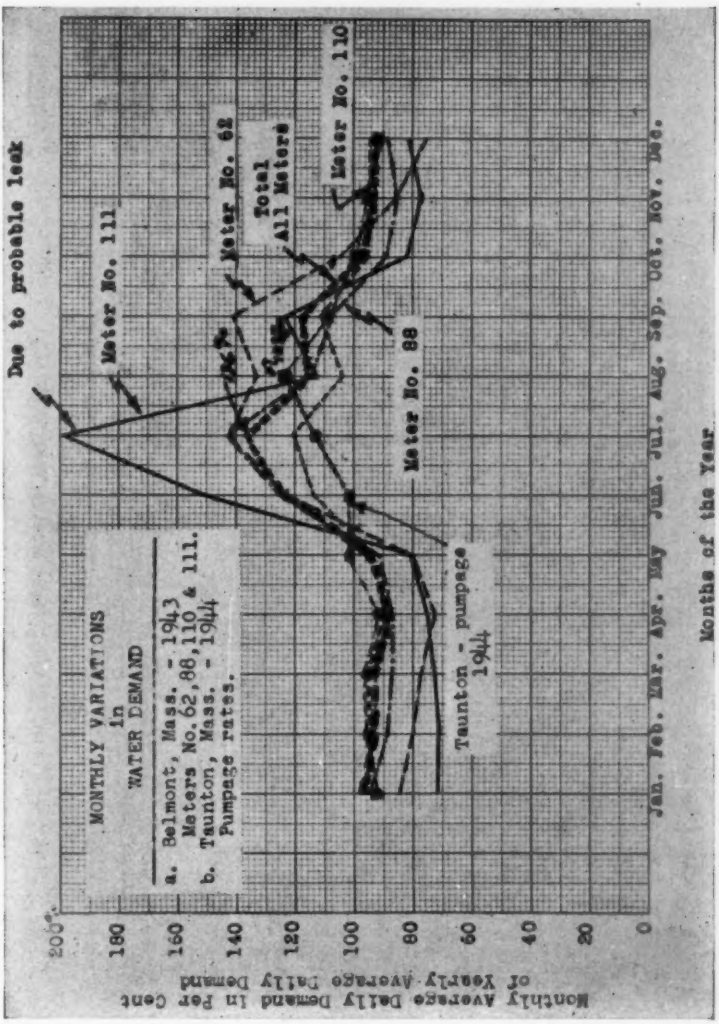

Due to probable leak
Meter No. 111
Meter No. 62
Total All Meters
Meter No. 110
Meter No. 88
MONTHLY VARIATIONS in WATER DEMAND
a. Belmont, Mass. - 1943
Meters No. 62, 88, 110 & 111.
b. Taunton, Mass. - 1944
Pumpage rates.
Taunton - pumpage 1944
Monthly Average Daily Demand in Per Cent of Yearly Average Daily Demand
200
180
160
140
120
100
80
60
40
20
0
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Months of the Year

FIG. 3.

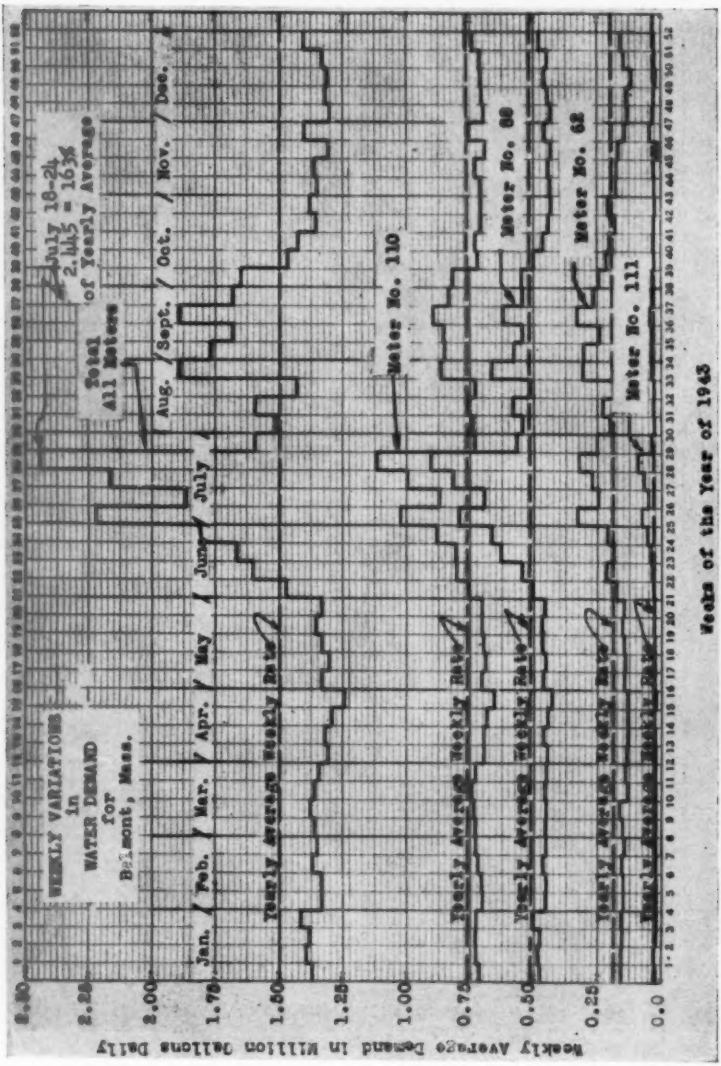

WEEKLY VARIATIONS
in
WATER DEMAND
for
Belmont, Mass.
July 18-24
2.445 = 163%
Total
of Yearly Average
All Meters
Yearly Average Weekly Rate
Meter No. 110
Meter No. 80
Meter No. 68
Meter No. 111
Jan. / Feb. / Mar. / Apr. / May / June / July / Aug. / Sept. / Oct. / Nov. / Dec.
Weekly Average Demand in Million Gallons Daily
Weeks of the Year of 1943

FIG. 4.

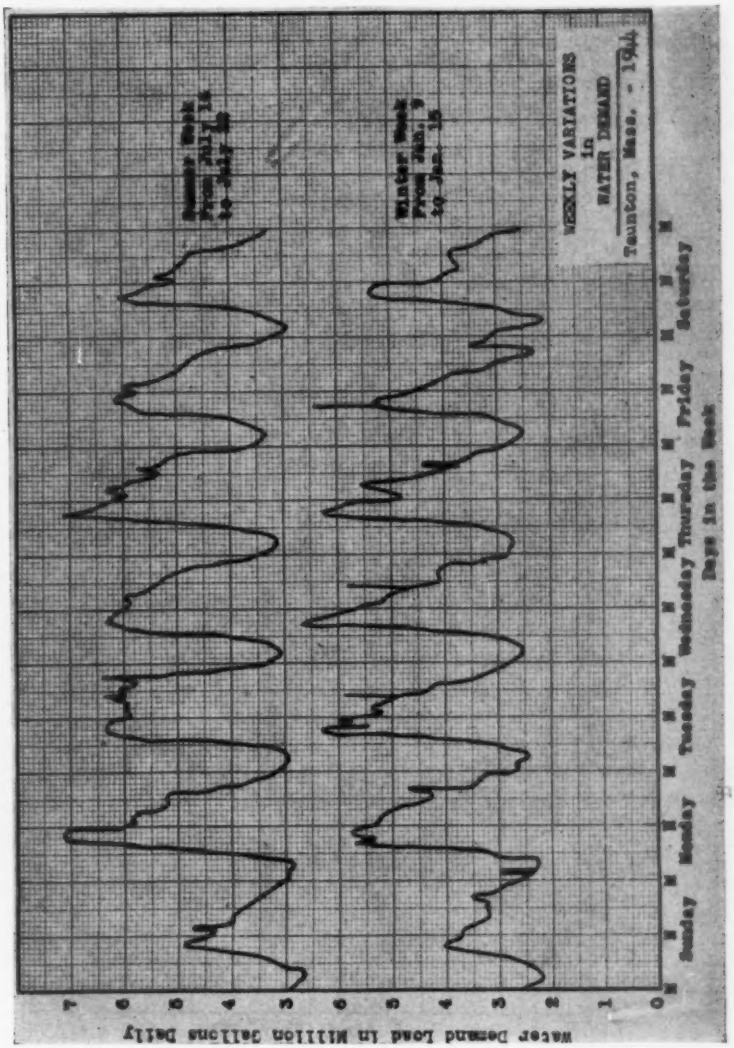

WEEKLY VARIATIONS
in
WATER DEMAND
Taunton, Mass. - 1944
Summer Week
From July 14
to July 20
Winter Week
From Jan. 9
to Jan. 15
Water Demand Load in Million Gallons Daily
0
1
2
3
4
5
6
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Days in the Week

FIG. 5

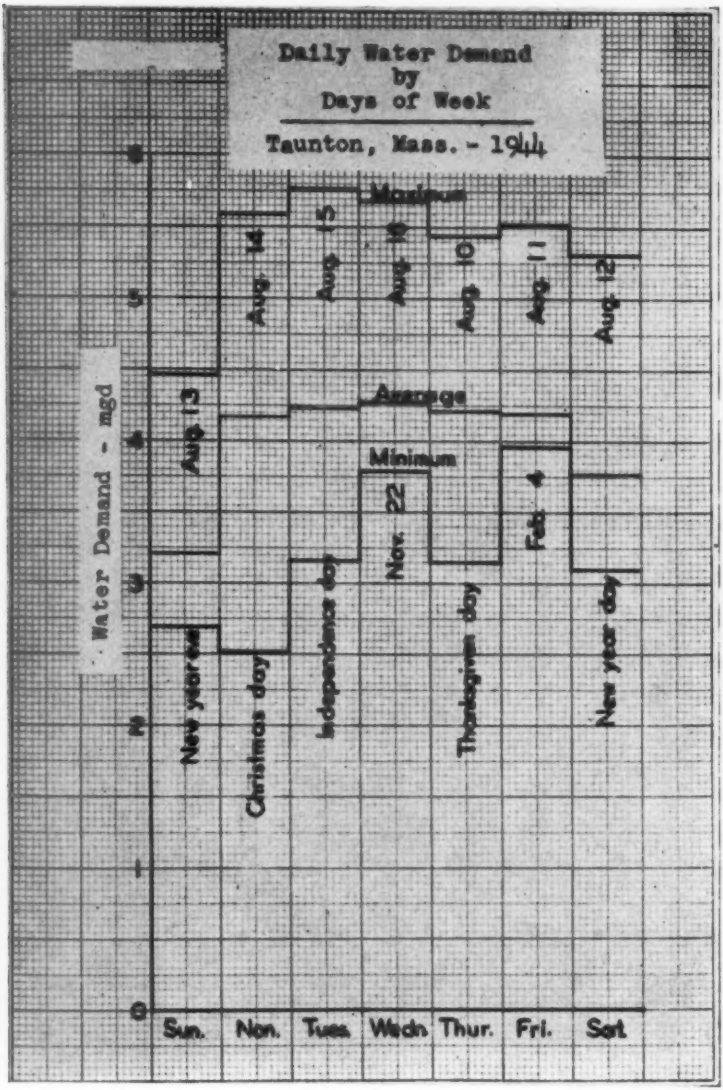

Daily Water Demand
by
Days of Week
Taunton, Mass. - 1944
Water Demand - mgd
Maximum
Average
Minimum
Aug. 14
Aug. 15
Aug. 16
Aug. 10
Aug. 11
Aug. 12
Aug. 13
Feb. 4
Nov. 22
New year eve
Christmas day
Independence day
Thanksgiving day
New year day
Sun.
Mon.
Tues.
Wedn.
Thur.
Fri.
Sat.

FIG. 6.

TABLE 4.—DAILY VARIATIONS IN TAUNTON PUMPAGES,* 1944
(Pumpages in mgd)

Month	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
Jan.	2.99	3.96	4.02	4.07	3.91	3.90	3.52
Feb.	3.02	4.02	3.98	4.03	4.25	3.72	3.67
Mar.	3.07	4.00	4.10	4.06	4.01	4.02	3.73
Apr.	2.88	4.15	4.04	3.93	3.94	3.98	3.58
May	3.40	4.19	4.15	4.58	4.26	4.27	3.98
June	3.06	4.02	4.31	4.22	4.55	4.56	3.75
July	3.57	4.66	4.53	4.65	4.67	4.69	4.39
Aug.	3.94	5.40	5.32	5.40	5.14	5.11	4.76
Sept.	3.29	4.07	4.35	4.32	4.21	4.43	3.94
Oct.	3.32	4.06	4.15	4.11	3.83	4.29	3.68
Nov.	3.04	3.88	3.95	3.90	3.81	3.84	3.54
Dec.	2.98	3.68	4.05	4.01	3.98	3.85	3.54
Yearly aver.	3.21	4.17	4.25	4.27	4.21	4.20	3.77

*Assembled from thesis by Chia-Tsun Hu.

high demand, except when some sporadic demand load, such as fire or large lawn-sprinkling load, modifies the pattern. This is illustrated by the Taunton data for typical summer and winter weeks (Figure 5).

A chart (by Vinas) of hourly pumpage rates for maximum, average and minimum days (Figure 7) shows similar patterns, except for the magnitude of each hourly demand. Another study (by Hu) of the day of maximum demand (Aug. 15, 1944) shows a pattern quite similar to that for Evanston, Ill., published by Paul Hansen (8) in 1926. Both curves have characteristic 9 or 10 A.M. peak demands and a second peak about 8 P.M., quite likely due to lawn sprinkling. The Taunton curve indicates that about 10% of the total daily demand was represented by rates greater than the daily average. The Evanston curve shows a somewhat higher percentage above the daily average.

Ewing's (5) analysis of Belmont Meter No. 110 district hourly variations in demand (Figure 8) shows quite similar patterns for days of average and minimum demands, and a curve not unlike Taunton

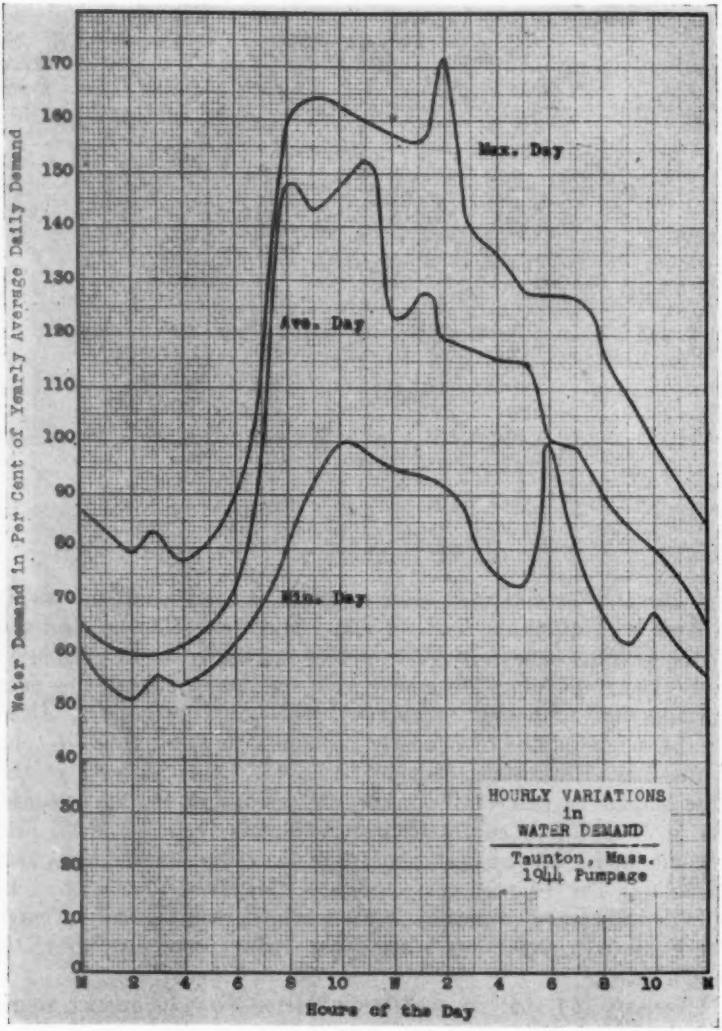

Water Demand in Per Cent of Yearly Average Daily Demand
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Max. Day
Ave. Day
Min. Day
HOURLY VARIATIONS
in
WATER DEMAND
Taunton, Mass.
1914 Pumpage
M 2 4 6 8 10 M 2 4 6 8 10 M
Hours of the Day

FIG. 7.

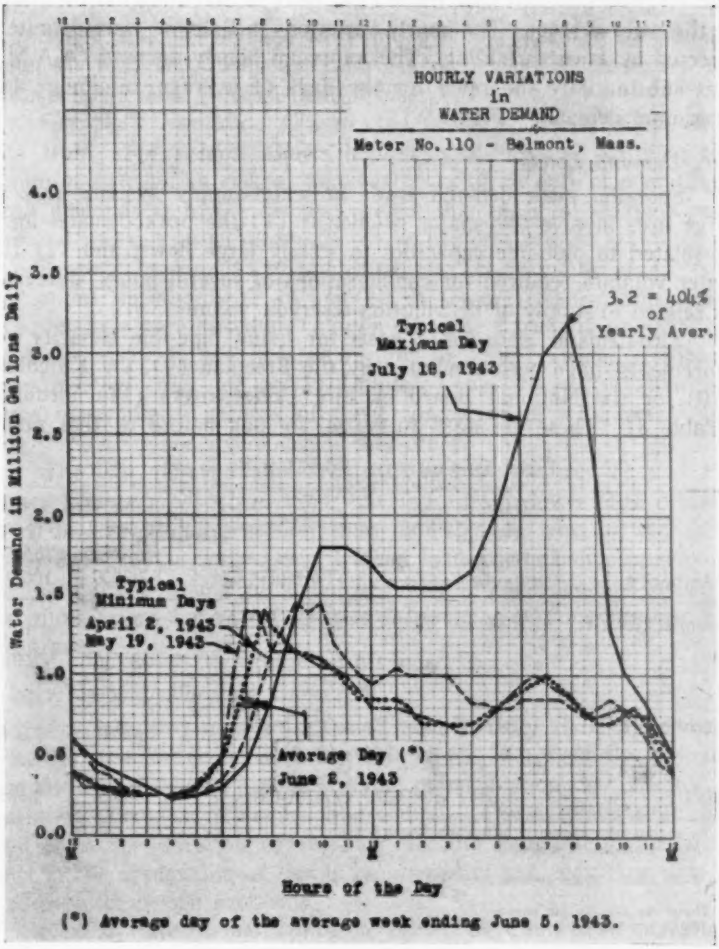

HOURLY VARIATIONS
in
WATER DEMAND
Meter No. 110 - Belmont, Mass.
Typical
Maximum Day
July 18, 1943
3.2 = 404%
of
Yearly Aver.
Typical
Minimum Days
April 2, 1943
May 19, 1943
Average Day (*)
June 2, 1943
Water Demand in Million Gallons Daily
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Hours of the Day
(*) Average day of the average week ending June 5, 1943.

FIG. 8.

and Evanston, except that the 8 P.M. peak is much higher, compared to the daily average. The hourly variations in Belmont were definitely affected by lawn sprinkling. The minimum hourly demand (4 A.M.) was substantially the same for the days of average, minimum and maximum demands (Figure 8).

Fire-Demand Loads

Sporadic peak demand loads in water-supply systems due to large fires involve two major problems: (1) the peak demand load, as related to pipe-line capacities to supply large flows, and (2) the water volumes required for conflagrations of several hours' duration, as related to supply or distribution-reservoir volumes.

Fire-demand loads, as a basis for fixing pipe-line capacity requirements, have been computed by the Freeman (9), the Kuichling (10), or the National Board of Fire Underwriters (11) formulas (Table 5). These are aged formulas, so long before us that many

TABLE 5.—COMPUTED FIRE-DEMAND LOADS

Authority	Date originally proposed	Formula*	Computed fire-demand load (gpm) for populations of 25,000	100,000
Freeman, John R.	1882	$q_1 = 250\ (1.7\sqrt{P} + 0.03P)$	2,313	5,000
		$q_2 = 250\ (\frac{P}{5} + 10)$	3,750	7,500
Kuichling, Emil	1897	$N = 2.8\ \sqrt{P}$ $q = 700\ \sqrt{P}$	3,500	7,000
NBFU‡	1916	$q = 1020\ \sqrt{P}\ (1\text{-}0.01\sqrt{P})$	4,845	9,180

*q = computed demand in gallons per minute.
P = population in thousands.
N = number of fire streams = $(\frac{P}{5} + 10)$ by Freeman.
†Based on 250-gpm fire streams.
‡NBFU = National Board of Fire Underwriters.

writers forget to reference their source. They all relate the potential peak sporadic fire-demand load in the distribution system to the magnitude of the population involved. The N. B. F. U. formula long has served as one element in establishing community fire-insurance

ratings, the ideal being to provide distribution storage sufficient to supply the peak fire-demand load for 10 hours (5 hours for populations up to 2,500) over and above the storage requirements for normal operational peak demand loads.

Graphic presentation (Figure 14) of data assembled by Vinas (3) from 1944 records shows highest peak demand loads in the Taunton distribution system were due as often to normal operational peak demands as to fire demand, except that the most extreme peak demand was due to an unusually severe fire on April 10.

A study by Hu (4) of published data on unusually severe conflagrations, together with an analysis of some 1,780 occasions when fire pressures were raised at Taunton pumping station, during the ten-year period 1935-1944, located records of seven extreme conflagrations in other cities and two in Taunton (Table 6). Illustrative patterns of graphical records of these conflagrations (Figures 9 and 10) show no similarity of one to any other.

The two most extreme fires in Taunton (Figures 11 and 12) during ten years—1935 to 1944—created a much lower peak demand load on the pumping station than indicated by any of the three formulas. However, the peak demand load reached the capacity of the pumping station. The actual or potential peak demand for these two fires might have been greater if pumping-station capacity had been ample.

Water Demand-Duration Curves

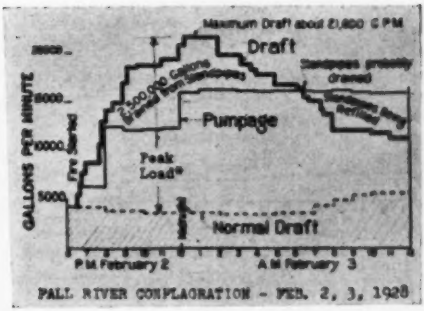
The foregoing data on seasonal, weekly, daily and hourly variations of the water-demand loads in three water-supply systems, graphically presented, gives curves corresponding to power-load variation curves or river-flow hydrographs. Power demand-duration and river flow-duration curves have become quite useful analytical aids in the application of power requirements and river-flow data to hydro-power design problems.

Similar water demand-duration curves have not been commonly used in water-works engineering problems. They could be quite useful in connection with the solution of many water-works problems and would become important analytical aids, should water-service rates related to water-demand loads become a more common practice.

TABLE 6.—PEAK FIRE-DEMAND LOADS AND EXTRA WATER REQUIREMENTS FOR EXTENDED FIRES

Location Date Population	Peak demand (mgd) Domestic and fire	 Fire demand	Extra water used (mg)	Fire duration (hr)	NBFU comparison (computed demand) Fire demand (mgd)	 Extra water required (mg)
Norfolk, Va. June 3, 1931 129,710*	21	12	3.6	14	14.4	6.0 L
Nashua, N. H. May 4, 1930 31,463*	10.8	9	5	19	7.2	3.0 M
Fall River, Mass. Feb. 2-3, 1928 115,274*	31	26.2	20	12	14.4	6.0 M
Nashville, Tenn. Mar. 22, 1916 118,342†	17.5	6.5	—	4½	14.4	6.0 —
Salem, Mass. June 25-26, 1914 43,697‡	26	22	16	13	8.6	3.6 M
Chelsea, Mass. Apr. 12, 1908 32,452‡	23	21	29	7½	7.2	3.0 M
Chicago, Ill. May 19-21, 1934 3,376,438*	—	101	69.5	56	29	12.1 M
Taunton, Mass. Sept. 12, 1942 37,455**	8.0[1]	6	1.79	8.7	8.4	3.5 L
Taunton, Mass. Apr. 10, 1944 37,455**	9.1[1]	4.2	0.7	6	8.4	3.5 L

* = 1930 census; † = 1920 census; ‡ = 1910 census; ** = 1940 census.
[1] = Maximum capacity of pumping station.
L = Extra water required was less than computed quantity.
M = Extra water required was more than computed quantity.



NOTE:—Standpipes furnished 7 mgd fire demand above pumping capacity.

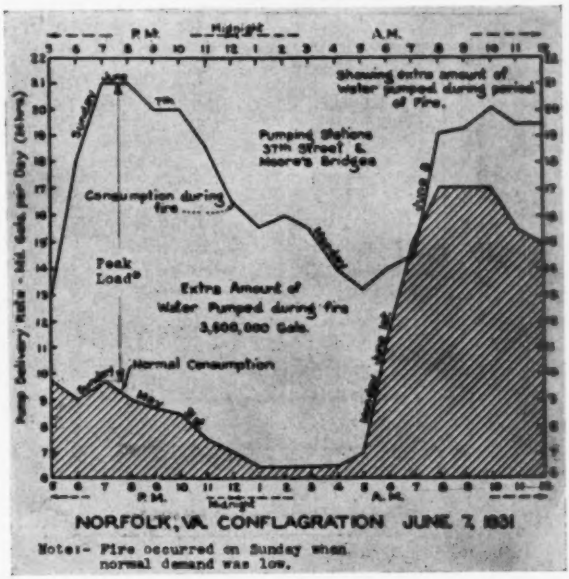
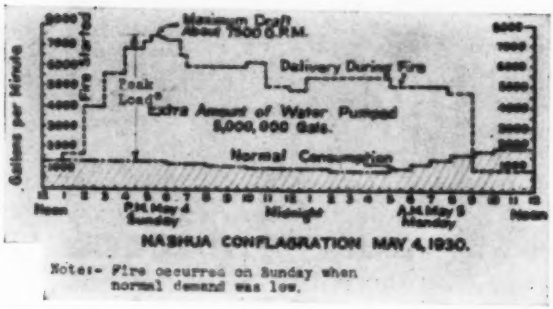

Showing extra amount of water pumped during period of fire.
Pumping Stations 37th Street & Moore's Bridges
Consumption during fire
Peak Load*
Extra Amount of Water Pumped during fire 3,500,000 Gals.
Normal Consumption
NORFOLK, VA. CONFLAGRATION JUNE 7, 1931
Note:- Fire occurred on Sunday when normal demand was low.

FIG. 9.—ILLUSTRATIONS OF FIRE-DEMAND LOADS ON WATER-SUPPLY SYSTEMS

*Peak fire load above normal demand.

Ref.—Jour. N.E.W.W.A., Vol. XLVI



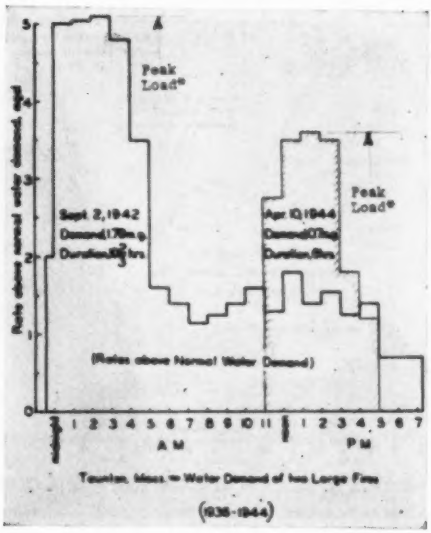


FIG. 10.—ILLUSTRATIONS OF FIRE-DEMAND LOADS ON WATER-SUPPLY SYSTEMS.
*Peak fire load above normal demand.
Ref.—Jour. N.E.W.W.A., Vol. XLVI

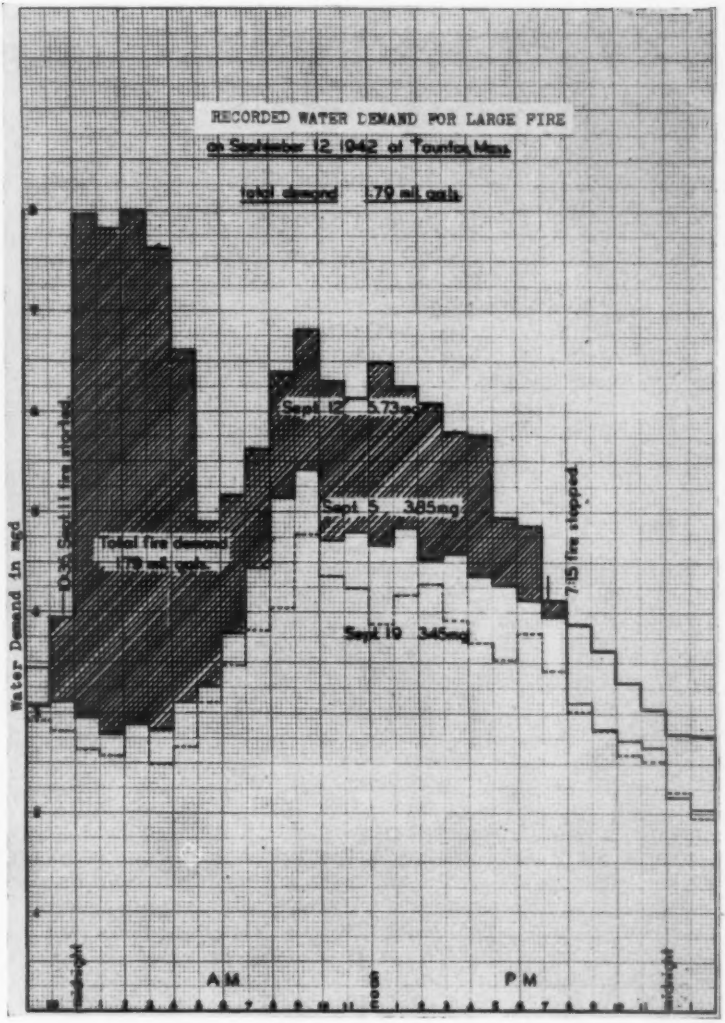

RECORDED WATER DEMAND FOR LARGE FIRE
on September 12, 1942 at Taunton, Mass.
total demand 1.79 mil. gals.
Sept. 12 5.73mg
Sept. 5 3.85mg
Sept. 10 3.45mg
Total fire demand 1.79 mil. gals.
0.35 Spindle fire started
7:15 fire stopped
Water Demand in mgd
Midnight
A M
noon
P M
Midnight

FIG. 11.

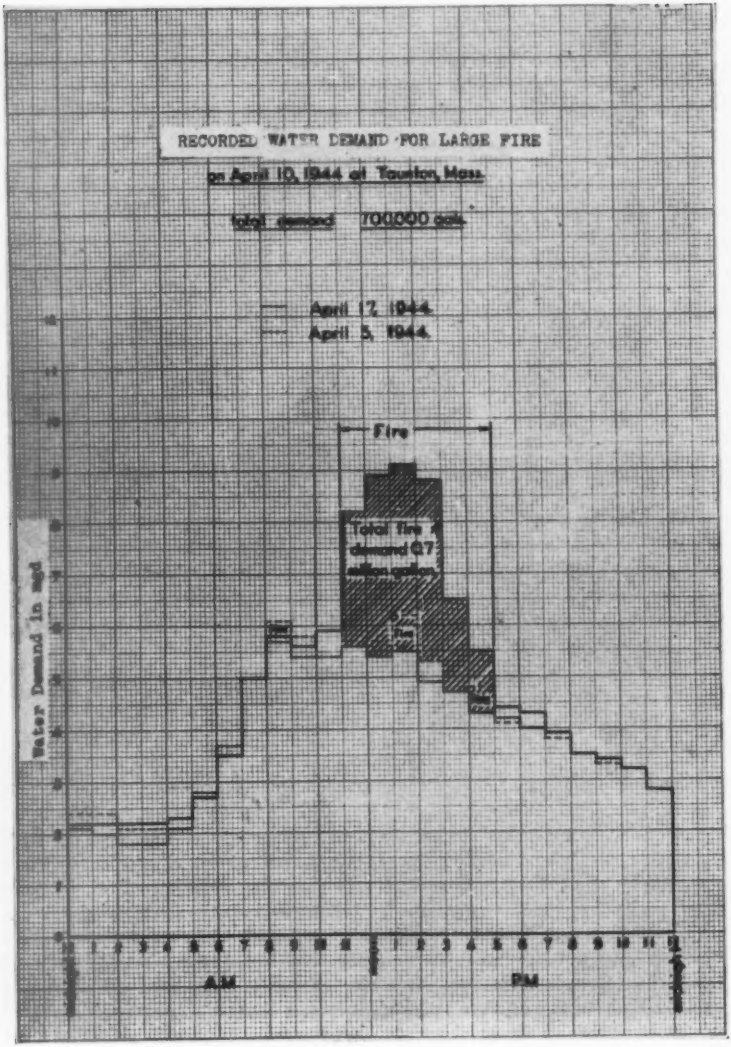

RECORDED WATER DEMAND FOR LARGE FIRE
on April 10, 1944 at Taunton, Mass.
total demand 700000 gals.
April 17, 1944.
April 5, 1944.
Fire
Total fire demand 0.7 million gallons
Water Demand in mgd
A.M.
P.M.

FIG. 12.

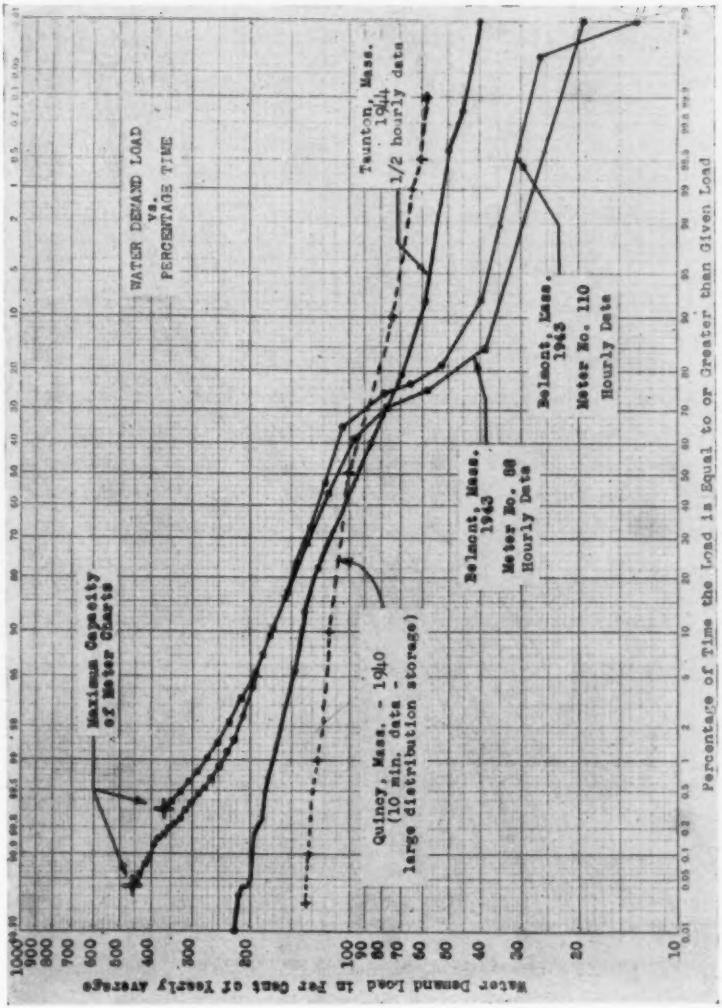

WATER DEMAND LOAD
vs.
PERCENTAGE TIME
Maximum Capacity
of Meter Charts
Quincy, Mass. - 1940
(10 min. data -
large distribution storage)
Belmont, Mass.
1943
Meter No. 88
Hourly Data
Belmont, Mass.
1943
Meter No. 110
Hourly Data
Taunton, Mass.
1944
1/2 hourly data
Water Demand Load in Per Cent of Yearly Average
Percentage of Time the Load is Equal to or Greater than Given Load

FIG. 13.

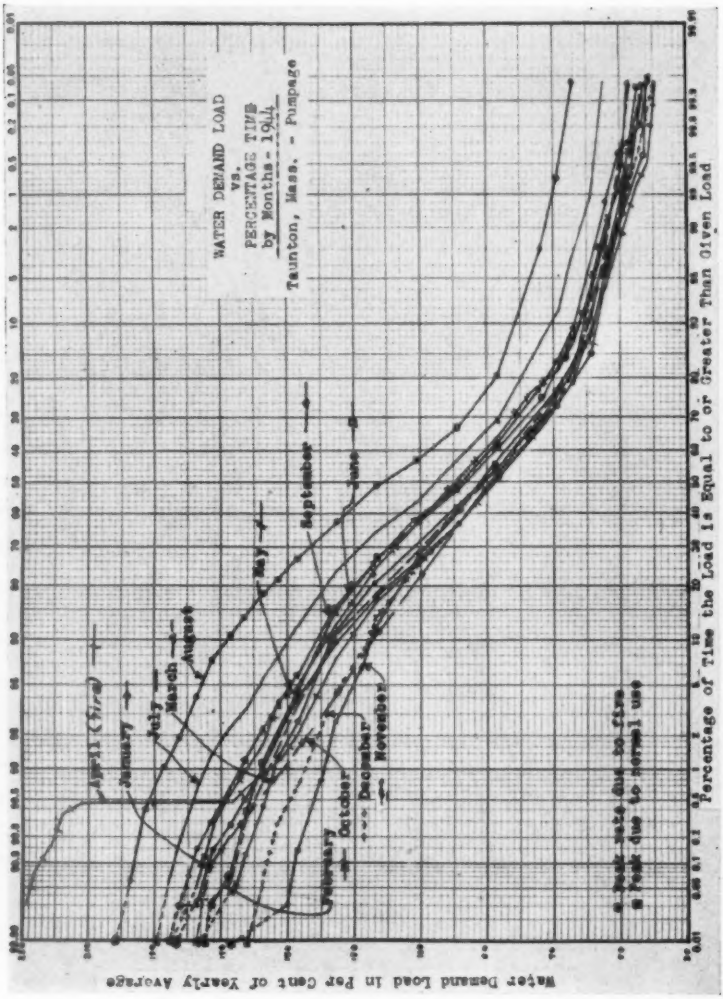

WATER DEMAND LOAD
vs.
PERCENTAGE TIME
by Months - 1941
Taunton, Mass. - Pumpage
Water Demand Load in Per Cent of Yearly Average
Percentage of Time the Load is Equal to or Greater than Given Load
April (Fire)
January
July
March
August
May
September
June
February
October
December
November
Peak rate due to fire
Peak due to normal use

FIG. 14.

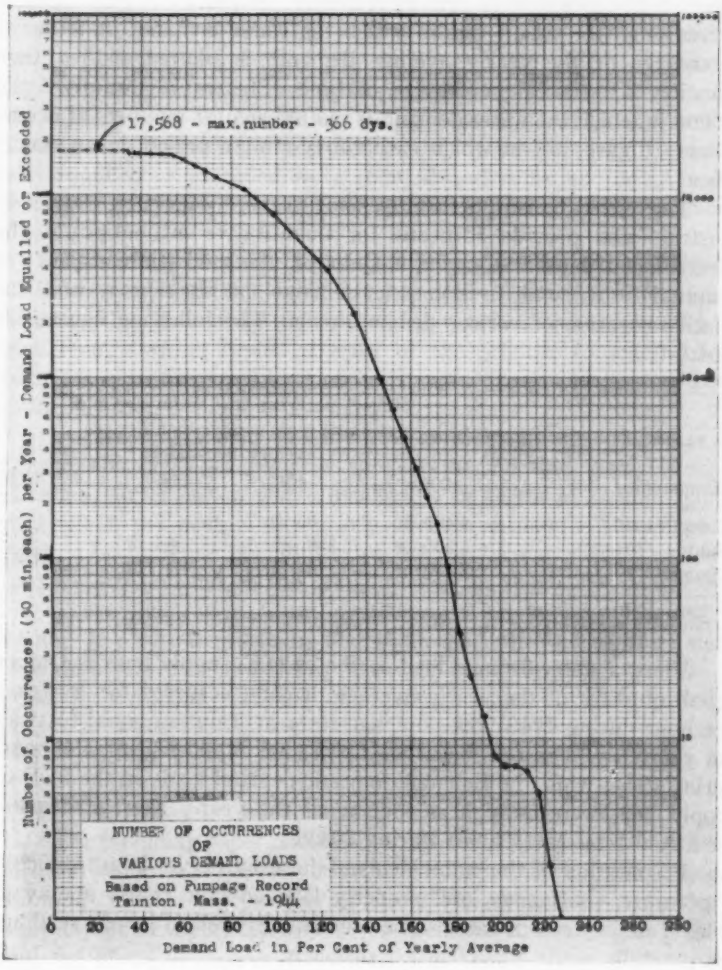

17,568 - max. number - 366 dys.
Number of Occurrences (30 min. each) per Year - Demand Load Equalled or Exceeded
NUMBER OF OCCURRENCES
OF
VARIOUS DEMAND LOADS
Based on Pumpage Record
Taunton, Mass. - 1944
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
Demand Load in Per Cent of Yearly Average

FIG. 15.

Water demand-duration curves were prepared from Quincy, Taunton and Belmont records (Figures 13, 14 and 15). Two types of curves might be used: one in which the water demand, in terms of percentage of the yearly average demand, is plotted against time duration in terms of percentage of time (Figures 13 and 14); the second in which the water demand is plotted against numbers of occurrences (Figure 15—in which each thirty-minute period = an occurrence).

The water-demand-percentage-time curves (Figures 13 and 14) illustrate and provide a means for quantitative evaluation of the effect of distribution storage (at Quincy), the industrial demand (at Taunton) compared to domestic demand (at Belmont), and the relative duration of various demand loads. The following figures are illustrative:

Community	Hours* per year that water demand was equal to or greater than per cent of yearly average demand			
	100%	140%	200%	400%
Quincy (1940)	4,400 hr	0.9 hr		
Taunton (1944)	3,800 hr	880 hr	4.4 hr	
Belmont† (1943)	5,400 hr	2,270 hr	350 hr	13 hr

*Computed from percentage time.
†Average of two meters.

Thus, a water-demand load on the M.D.C. supply lines at Quincy equal to 140% of the yearly average demand occurred for less than one hour during 1940; the pumpage rates at Taunton equal to twice the yearly average rate occurred for a sum total time of 4.4 hours during 1944; while the Belmont domestic demand loads on the M.D.C. supply lines were as high as four times the yearly average demand for a sum total of 13 hours during 1943.

Preparation of the water demand-duration curves is not difficult, if accurate, continuous, and properly labelled flow charts are available. Tabular records can also be used equally well, if hourly readings are carefully made and recorded routinely.

As an example of the water demand-duration curve preparation, in the Belmont study (by Ewing) the M.D.C. meter charts were ob-

tained, through the courtesy of Mr. Harold S. Toole, Chief Water Supply Engineer, M.D.C., and a table was prepared for each month (Table 7), with columns for water-demand readings sub-divided to give a sufficient number of points, between the extreme minimum and extreme maximum reading, to produce a reasonable smooth curve when plotted. The number of hourly periods (half-hourly used in Taunton—ten-minute periods used in Quincy study) that a given rate was equalled or exceeded were counted and recorded for each day, and then added up to obtain the number of occurrences per month (Table 7).

A summary of water demand-duration data for Belmont (Table 8) illustrates the combining of monthly data to obtain a yearly record. The monthly percentage figures, added together and divided by 12, give results within limits of error of the original records. Adding numbers of occurrences by months is just as easy and is statistically more accurate.

Taunton 1944 data (Figure 14, semi-log plotting) illustrate the considerable variance between the several monthly water demand-duration curves, when water demand is in terms of million gallons daily or in per cent of the yearly average demand. The curve for April, 1944 (Figure 14), illustrates the spectacular effect of a severe sporadic fire demand on the demand loads for short-time durations.

These illustrative water demand-duration curves (Figures 13, 14 and 15) were prepared by simple plotting, with no effort at statistical analysis. If and when accurate water-demand records are generally available and the application of water demand-duration curves to water-supply engineering is better understood, then more mathematically correct statistical analyses may be desirable.

Summary

The foregoing paper makes of record certain graphic data believed to be of value to water-works men. Also illustrative water demand-duration curves are presented (Figure 13), which show more clearly than any other method the value of distribution storage (at Quincy) and the effect of industrial demand (at Taunton), as compared to domestic demand (at Belmont), on the duration of relatively high water-demand loads on water-supply systems.

TABLE 7.—NUMBER OF OCCURRENCES OF WATER-DEMAND LOADS, BELMONT, MASS., DURING JANUARY, 1943 — METER #110

Day	Water demand in mgd													
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
	Numbers of occurrences of 1-hour average* during each day													
1	24	21.5	19.5	18	16.5	16	14.5	13	6	4	1	—	—	—
2	24	22	19	17.5	17	16	15	12.5	6.5	4.5	1.5	0.5	—	—
3	24	23	19	17.5	16.5	15	14	8	6	5.5	2.5	1.5	1	—
4	24	22	19	17.5	17	17	15	9	6	5	1	—	—	—
5	24	24	20	19	18	17.5	12	5	3	1.5	0.5	—	—	—
6	24	24	19	17.5	17	16	11	8	4	2	1	0.5	—	—
7	24	22	18.5	17.5	17	16	11.5	8	4.5	1.5	1	0.5	—	—
8	24	24	23.5	23	22	21.5	18	13	12.5	8	1.5	0.5	—	—
9	24	21	19	18	16.5	16	15.5	13	8.5	4	1	0.5	—	—
10	24	21.5	18.5	17.5	17	17	16	12.5	7	5.5	3.5	2	1	—
11	24	21.5	19.5	18.5	18	18	13.5	9	7.5	5	3.5	3	1	0.5
12	24	21.5	19	18	18	17	14	8	5	3	1	0.5	—	—
13	24	22	20	19	18	17.5	11.5	8.5	5	4	1.5	0.5	0.5	—
14	24	22	19.5	18	18	17	13	8.5	4.5	1.5	1	0.5	—	—
15	24	22.5	20	18.5	18	18	17	8	6.5	2	1	1	0.5	—
16	24	23	20	19	18	17	16.5	16	6.5	3	0.5	—	—	—
17	24	24	19	17.5	17	16.5	15.5	12.5	6.5	6	4	1.5	1.5	0.5
18	24	24	20	19	18	18	16	12	6	4.5	3	1.5	0.5	—
19	24	24	21.5	19	18	17.5	17	12	8.5	3	1	—	—	—
20	24	21	20	18.5	18	17	12	8	6.5	3	1.5	0.5	—	—

TABLE 7.—NUMBER OF OCCURRENCES OF WATER-DEMAND LOADS, BELMONT, MASS., DURING JANUARY, 1943—METER # 110 (*Continued*)

Day	Water demand in mgd													
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
	Numbers of occurrences of 1-hour average* during each day													
21	24	21.5	19.5	18.5	18	17.5	15	8.5	4.5	2	1	0.5	—	—
22	24	21.5	20	18.5	18	18	17	8.5	4.5	2	1	0.5	—	—
23	24	22	20	19	18	17.5	17	13	8	4	1.5	—	—	—
24	24	22	20	17.5	17	16	15	10.5	6.5	6	4	2	1.5	0.5
25	24	22	20	19	18	18	16	10	5.5	5.5	3	1.5	0.5	—
26	24	24	20	18.5	18	17.5	15.5	9.5	4	4	2	1	0.5	—
27	24	24	20	18.5	18	17.5	14	6	4.5	1.5	1	0.5	—	—
28	24	21.5	20	18	18	17.5	13	8.5	6.5	2.5	1	0.5	—	—
29	24	23	19.5	19	18	18	15	9.5	6	1.5	0.5	—	—	—
30	24	21.5	20	19	18.5	17.5	16.5	12	7	3.5	1	—	—	—
31	24	24	18.5	17.5	17	16	15	10.5		6	3.5	2	1	—
Totals	744	697.5	611	573	550	532.5	457.5	311	190	115	52	23.5	9.5	1.5
% Time	100	93.75	82.12	77.02	73.92	71.57	61.49	41.80	25.54	15.46	6.99	3.16	1.28	0.20

*Based on continuous meter charts.

TABLE 8.—YEARLY SUMMARY OF WATER DEMAND-DURATION DATA AT BELMONT, MASS. — METER #110 — FOR YEAR 1943

Yearly average daily demand—0.7619 mgd

Water demand		Number of occurrences* of water demand equal to or greater than given rate													% of
M.G.D.	%†	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals	time ‡
0.1	13.13	744	672	744	720	744	720	744	744	720	744	720	744	8,760	100
0.2	26.25	744	672	744	717	744	720	744	744	720	744	720	744	8,757	99.97
0.3	39.38	697.5	627.5	708	628	646.5	686	706.5	704.5	720	661	625	671	8,081.5	92.25
0.4	52.50	611	549.5	609.5	572	595.5	589.5	603	605.5	634	593.5	568	593.5	7,124.5	81.33
0.5	65.63	573	519.5	580.5	551	570.5	557	577.5	568	568	568.5	537	564.5	6,735	76.88
0.6	78.75	550	498.5	555.5	532.5	551.5	541	553	549	541.5	551	521	549.5	6,494	74.13
0.7	91.88	532.5	481.5	539	511.5	529.5	527	532	331.5	526	533	509.5	534.5	6,287.5	71.78
0.8	105.0	457.5	408.5	464.5	410.5	430	507	502.5	492.5	502	475.5	450	562.5	5,663	64.65
0.9	118.1	311	266.5	300.5	268.5	282.5	460.5	440	399	432	323	297.5	320	4,101	46.82
1.0	131.3	190	172.5	197.5	175	178	365.5	360.5	319	328	219.5	204.5	211	2,921	33.34
1.1	144.4	115	118	130.5	111.5	102.5	289.5	310.5	244	249.5	147.5	130	130	2,078.5	23.73
1.2	157.5	52	56	76	59	60.5	227	254	167	176.5	91.5	80	72	1,371.5	15.66
1.3	170.6	23.5	30.5	44.5	35	39.5	176	206.5	111	123	57	48.5	35	930	10.62
1.4	183.8	9.5	15	23	17.5	23	127	162.5	67.5	85	32.5	29.5	17.5	609.5	6.96
1.5	196.9	1.5	5	10.5	7	13	84	123	37.5	53	12.5	14.5	6.5	368	4.20
1.6	210.0	—	0.5	2	1	4.5	61.5	90	22	28	3	4.5	1	218	2.49
1.7	223.1	—	—	—	—	0.5	37	70	14	12	—	2.5	—	136	1.55
1.8	236.3	—	—	—	—	—	27	52.5	10	4.5	—	2.5	—	96.5	1.10
1.9	249.4	—	—	—	—	—	19	43.5	7	1.5	—	2.5	—	73.5	0.84
2.0	262.5	—	—	—	—	—	16	38	3.5	—	—	0.5	—	58	0.66

TABLE 8.—YEARLY SUMMARY OF WATER DEMAND-DURATION DATA AT BELMONT, MASS. — METER #110 — FOR YEAR 1943
(*Continued*)

Yearly average daily demand—0.7619 mgd

Water demand		Number of occurrences* of water demand equal to or greater than given rate												% of
M.G.D.	%†	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals	time ‡
2.1	275.6	—	—	—	—	—	12	32	2	—	—	—	—	46	0.53
2.2	288.8	—	—	—	—	—	10.5	28	1.5	—	—	—	—	40	0.46
2.3	301.9	—	—	—	—	—	8	23.5	1	—	—	—	—	32.5	0.37
2.4	315.0	—	—	—	—	—	8	19	—	—	—	—	—	27	0.31
2.5	328.1	—	—	—	—	—	7.5	15	—	—	—	—	—	22.5	0.26
2.6	341.3	—	—	—	—	—	6.5	13.5	—	—	—	—	—	20	0.23
2.7	354.4	—	—	—	—	—	5.5	11	—	—	—	—	—	16.5	0.19
2.8	367.5	—	—	—	—	—	4.5	10	—	—	—	—	—	14.5	0.17
2.9	380.6	—	—	—	—	—	4.5	8.5	—	—	—	—	—	13	0.15
3.0	393.8	—	—	—	—	—	3	8	—	—	—	—	—	11	0.13
3.1	406.9	—	—	—	—	—	2.5	5	—	—	—	—	—	7.5	0.086
3.2	420.0	—	—	—	—	—	2	4.5	—	—	—	—	—	6.5	0.074
3.3	433.1	—	—	—	—	—	1.5	3.5	—	—	—	—	—	5	0.057
3.4	446.3	—	—	—	—	—	1.5	2.5	—	—	—	—	—	4	0.046
3.5	459.4	—	—	—	—	—	1.5	2	—	—	—	—	—	3.5	0.040

*Each occurrence = rate averaged over 1-hour period.
†Water demand as per cent of yearly average (0.7619 mgd).
‡Number of occurrences each month ÷ 8,760.

Many water departments are not equipped nor organized to obtain proper data from which water demand-duration curves might be prepared. Accurate recording water-demand and rate-of-flow metering equipment is required, together with an operating routine of labelling, collecting and filing the meter charts.

It is suggested that these water demand-duration curves, so useful in hydro-power studies, may be useful aids in water-works engineering, and particularly in water-rate studies, if water demand is to be considered in rate schedules.

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PRESENT-DAY USES OF CONE VALVES

BY CARL J. WILCOX*

[*Read September 20, 1950.*]

ROTARY-TYPE plug valves have been used since antiquity. However, it has been only in the past 25 years that the modern, precision-built, rotary plug valve has been used for shut-off and control-valve service on water-distribution and other services. It is commonly known as a Cone Valve.

The cone valve was introduced and became accepted because of three distinct advantages: (1) ease of operation; (2) tightness when seated; (3) advantageous flow control (throttling characteristics). To these three reasons has been added a fourth, since time has proven the cone valve to be appreciably free of wear and, therefore, to have a long life.

There are at present two distinct types of cone valves on the American market, those which move axially to unseat before rotation and those which have no axial movement. It is the first of these two types which will be discussed in this paper, since the second type has not been used extensively in the water-service field. They are used to a great extent in the oil industry.

Cone valves can be classified in two categories: full-area round ports and reduced-area Venturi pattern with trapezoidal plug ports. The full-pipe-area round-port valve is the most common and has been manufactured in large numbers. The reduced-area valve is a newcomer to the market and is designed for a specific function—namely, as a shut-off valve. The full-area, round-port cone valve can be divided into those operated manually and those operated by mechanical means. Of the mechanically operated valves, the most commonly used is the hydraulic-cylinder-operated valve. Other means of operation are by electric motors or by pneumatic cylinders or motors. Various control systems for several kinds of operation will be discussed somewhat later in this paper.

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Manual valves are used extensively in pipe-line and distribution work. In this application the ease of operation of the Rotovalve is its greatest advantage. Most water-works operators are familiar with the difficulties of shutting gate valves under emergency conditions, such as a broken main. It is often necessary to close one gate valve as far as possible and then repeat the process at the next valve up the line. By working at the various valves successively, it is finally possible to shut off the main, but a long interval of time has elapsed between the time of the break and the final shut-off. The rotary plug valve can be closed by one man against the full, designed pressure differential and opened again without equalizing the pressure on the opposite sides of the valve. The serious objection to using cone valves lies only in one factor—the much greater cost of the cone valve over a gate valve of the same size. There is, however, one factor which allows us to reduce this disparity of cost. Size for size, the cone valve has a smaller friction loss than a gate valve. The obvious answer is to use a cone valve of smaller size, with reducing and increasing sections from the full pipe diameter. The amount of reduction to be used is determined by balancing the cost of the various smaller-size valves with their associated reducers and increasers against the total head loss in the valve and the tapered sections.

The total head loss allowable is a function of the type of system and the velocities in general use. As pointed out in the article, "The Use of Cone Valves in Distribution Systems", by Laurence Goit and Laurie Leedom, the city of Newark has installed 24″ cone valves in 60″ lines. Also, in the same paper, the advantages of using eccentric reducers and increasers are well described.

In evaluating the losses, the loss through a full-open cone valve can be taken as that in an equivalent length of straight pipe. The losses in increasers and reducers can be found in various handbooks and a balance sheet quickly drawn up, giving sufficient data to determine the optimum size of the cone valve. It is true that the monetary value of being able to shut the valve quickly in case of emergency is hard to evaluate. However, I believe that in the final analysis the cone valve is justified in certain key locations on most systems.

The uses of mechanically operated cone valves are so multitudinous that it will be impossible for me to do more than explain a few of the more common uses and indicate some others.

The hydraulic-cylinder-operated valve, which obtains its working fluid from the line in which it is installed, is perhaps the most generally used in the water-works field. Among the various applications of this valve are the following: as a check valve on a pump discharge; as a remotely controlled stop valve; as a pressure-reducing valve, and as an altitude-control valve.

The hydraulically operated cone valve can be adjusted to open and close over a wide range of time. The minimum operating time is of the order of 3 sec and the maximum about 5 min. This range can be extended with special equipment, which is rarely required in water service. The independent adjustment of opening and closing time makes the valve particularly advantageous as a pump check-valve, to minimize water-hammer. Controls are selected to give the best results for each individual problem.

As a remotely controlled stop valve, the hydraulic Rotovalve is generally installed with solenoid-operated control, so that it can be actuated by a pushbutton at any convenient location. Indicating lights, to show whether the valve is open or shut, can be placed at one or more locations.

As a pressure-reducing valve, the cone valve can function to maintain constant pressure on the downstream side of the valve, regardless of the upstream pressure. Various control methods are used, some being all hydraulic, so that no electricity is required. This is often advantageous in isolated locations or where power-line failures may occur frequently. Low pressures can normally be maintained within plus or minus two pounds of the desired setting, where the pressure differential across the valve does not exceed about 60 lb. Greater differentials result in correspondingly higher control limits.

The altitude-control valve or level-control valve is used to maintain water level in tanks, reservoirs, basins, etc. The level control is achieved by a cone valve in the intake line, which is operated remotely by a float, installed in the reservoir, responding to changes in level. The amount of fluctuation is transmitted to the valve control either mechanically, electrically, or pneumatically.

On altitude tanks cone valves may be used in either a one-pipe or two-pipe system. For the one-pipe system, the valve is controlled

so as to admit water into the tank, when the level has dropped to some predetermined point, and also to open and discharge water from the tank, when the pressure on the line drops below the normal system pressure. The two-pipe system has a separate inlet and outlet, and the valve operates only to keep a certain level in the tank by controlling the flow in the inlet pipe.

Hydraulically operated cone valves are also used as emergency line check-valves, in which case the operation is automatic and is initiated either by excess velocity or by reverse flow.

The valve uses just described were all based on the standard, hydraulically operated valve, using fluid from the pipe line for operation. The basic valve is identical in each case and varies only in the control system applied to it. Most of these control systems can be applied with some modification to electric-motor-operated valves, which have certain advantages where power is available and the fluid being handled in the line is unsuitable for use in the hydraulic cylinder, due to chemical contamination or too great a percentage of suspended solids. If hydraulic operation is required under these conditions, an accumulator system may be used. These consist of a pressure tank, a sump tank, and the necessary pumps and air compressors. Such sytems are generally filled with oil rather than water.

In order of cost, the hydraulic valve operated with line fluid is generally the cheapest, with motor-operated next, and hydraulically operated with accumulator system the most expensive. If, however, there is a large number of valves installed in one station, so that they can be served with one accumulator system, the total cost may be less than that of individual electric-motor-operated valves.

The use of a reduced size of full-area cone valve to decrease the cost of the installation, as described before, has led to the development of a cone valve which contains within itself the increaser and decreaser. By elongating the waterway in the direction of the plug axis and making it rectangular in shape, the size of the plug and, therefore, the body can be reduced. A reduction in material and, therefore, in cost results. Valves of this general shape have been in use in the oil industry for many years, although they have no provision for axial motion for seating and unseating. A study of head losses through various reductions of area, compared to the size and weight

of the resulting valve, has led to a design which has an area through the plug approximately 40% of the full area of the pipe. This is equivalent to putting a 12½″ valve in a 20″ line, and you have no doubt seen Venturi throats as small as 10″ in a 20″ line. A valve of this type has a loss slightly higher than a full-size gate valve and is approximately 25% higher in cost than the gate valve. The additional loss is no greater than that generally found to be economical with a reduced-size full-area valve and is usually found to be insignificant in the overall losses. Their general application is in distribution systems, when the velocities are relatively low. The additional premium over a gate valve must be written off by evaluating the ease of operation, the sureness of operation under abnormal conditions, and the freedom from wear and deterioration. The valves are so designed that in the full-open position they are seated tightly, so that no foreign material can get behind the plug and so that no scale can form on the seats or on the plug and body surfaces. Since valves in water lines may stay in the wide-open position for long periods of time, this is necessary, so that they may be closed without trouble when required.

Valves of this type are for general use as stop-valves in distribution systems and, as such, are manually operated and designed to be buried in the ground without a vault. While these valves in themselves are rather new, the full history of the development of the cone valve is behind them, so that one should not look at them as a new development, but rather as a logical outgrowth of the full-area valve. I am fully confident that in the next few years the use of these valves in key points in distribution systems will be quite common. Studies of individual distribution systems would indicate the locations for this type of valve, to sectionalize the lines properly, so that a quick and sure shut-off can be obtained if a break occurs.

I have tried to cover most of the applications of cone valves at the present time, particularly as applied to the water-works field, in which they got their start. They are finding increasing applications in other fields, in which their two big advantages of tight shut-off and ease of operation make their use imperative.

Discussion

William W. Brush (New York, N. Y.). I should like to ask whether you determined approximately, with the ordinary cone valve, manually operated in a distribution system, what range you would move the valve through before you would probably get an unbalanced force that would close the valve, if you did not continue to operate it and it was free to turn. As I see it, when you get the relatively high velocities, we know that some valves would close. The question I ask is: About how many degrees of angle would you probably turn before it would reach the position where the resulting force closed it?

Mr. Wilcox. It is sufficient to close it if the mechanism had not broken up. They would not close by themselves. Actually the hydraulic unbalance carries it about 45°. Certainly probably 30° or 35° would be sufficient to move it.

Syd. Wilson [of Atlas Mineral Products Co.]. Have you had an opportunity to observe the operation of these valves after they have stood idle for a long period of inactivity?

Mr. Wilcox. We have, sir. We don't know exactly, of course, how long some of these have stood, because they have evidently operated without any trouble, and therefore we did not hear about them. But we do know that some have operated after standing for periods of two or two and a half years.

Truman H. Safford (Boston, Mass.). I notice you said they operated on pressure drop. Have you ever used this type of valve, say, in lieu of a surge suppressor? In other words, suppose you had a discontinuance of power and a shutdown; would it do you any good to open up to prevent the bang of the pump?

Mr. Wilcox. Yes, you could open these.

Mr. Safford. On a simple installation they might be used instead of the surge suppressor?

Mr. Wilcox. Yes, but generally we find it cheaper to put the surge suppressor in. We have put in two installations of Rotovalves as surge suppressors.

Mr. Brush. If you were operating a distribution system and had a number of these valves in the system, how often would you consider it desirable to have a valve moved on the seat?

MR. WILCOX. We feel that probably once a year should be the minimum, but we realize that that would very rarely get done.

LINN H. ENSLOW (New York, N. Y.). Will the packing get hard as it does in the ordinary gate valves?

MR. WILCOX. To a certain extent. And that is something that depends mainly on the type of packing you use. We use a graphitic packing to lubricate. Of course, in a period of time it is going to get hard. We have had very little trouble with leakage over a period of years with them.

MR. ENSLOW. How do you lubricate the packing?

MR. WILCOX. It is just lubricated with this installed graphite.

MR. ENSLOW. No alemite connection?

MR. WILCOX. No. But on a lot of our valves we do install grease fittings, so that you can lubricate the pump as well as the packing glands. Generally, however, we do not feel it is necessary.

RICHARD HAZEN (New York, N. Y.). Would you expect that over a period of years there would be no maintenance required?

MR. WILCOX. Practically no maintenance.

MR. HAZEN. But if there was some, what would it be?

MR. WILCOX. Packing the glands.

MR. HAZEN. That would mean digging up the valve or, at least, the top part, and disassembling?

MR. WILCOX. That is right. You would not have to disassemble the mechanism. The packing glands are outside the mechanism housing.

MR. HAZEN. How about lubrication of the mechanism itself?

MR. WILCOX. The mechanism will be sealed and lubricated. In other words, you put grease or heavy oil in and that lasts for years.

MR. HAZEN. Fifteen years?

MR. WILCOX. Maybe. That is an oil problem—deterioration. But the valves should be looked at occasionally. Of course, a totally buried valve is pretty hard to look at. You may install a valve in one place and it will last 15 years, whereas another one will last two.

SANITARY PROTECTION OF WATERSHEDS ARE WE OVERDOING OR UNDERDOING IT?

BY ARTHUR D. WESTON*

[*Read September 20, 1950.*]

Reasonable protection of public water supplies is necessary, but experience may show that during the next 60 years the cost of protection, as afforded in the present age, may not be justified in view of the limited benefits resulting to the public health. In other words, the same amount invested in other phases of environmental sanitation may show greater benefits to the community as a whole. It is the purpose of this paper to point out to the members of our Association the problem which I feel that they will be faced with in future years. As I am more experienced with Massachusetts' conditions, I shall use that state as an example.

PROBLEM

Recent statistics, supplied by the Division of Sanitary Engineering of the Massachusetts Department of Public Health, will show that about 98% of the population of Massachusetts is at present contained in cities or towns supplied in whole or in part with water from public water supplies, either district, municipal or privately owned. These statistics further show that this state is the third most densely populated of all the states of the union and that this density, according to the United States Census of 1950, is in excess of 600† per square mile, as compared with about 284 per square mile in 1890. We may, therefore, readily see that not only is the public health of a large population dependent upon a safe water's being supplied, but—because of the high density of population—the spread of this population, if their sanitary habits are uncontrolled, could constitute a hazard of considerable magnitude. In this connection it is interesting to note that a committee of the New England Water Works Association recognized as early as 1927 the importance of watershed protection. As a

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†Based on preliminary 1950 Federal Census estimate for Massachusetts of 4,711,753. Land area of state estimated at 7,838.7 sq mi.

result of their studies regarding "A System of Sanitary Scoring of Water Supplies," they suggested that penalties be imposed under their proposed system of scoring of surface supplies as follows:—

". . . Score for no hazard 60

"*Base Penalties for Hazards Connected with Sources of Supply*:—

1. Population on watershed in 50-mile zones of intake
   (a) Contributing indirect pollution or where sewage is diverted from drainage area,
   $-2\sqrt{P_1 + 0.7P_2 + 0.39P_3}$ etc.
   (b) Contributing direct pollution (sewage)
   $-8\sqrt{P_1 + 0.7P_2 + 0.39P_3}$ etc.
   P_1 = population in first zone per square mile of total drainage area
   P_2 = population in second zone per square mile of total drainage area, etc.
2. Highways and railroads (per lineal mile per square mile of watershed) ..... —1
3. Lumbering, laboring camps, hunting, etc.
   (a) Lumbering, labor camps, etc. ..... —2
   (b) Hunting, picnicking, etc. ..... —1
4. Animal pollution
   (a) Direct ..... —2
   (b) Indirect ..... —1
5. Industrial wastes ..... —1 to —5
6. Leaky intake, suction main or gravity main from relatively unpolluted source passing through sewage-polluted water —25 to —60"

Certain credits were given by the committee, according to the degree of treatment rendered the water, but where the water was untreated and the sole protection was in the adequacy of enforcement of regulations, it will be seen that a scoring of zero could be possible, as compared with a score for a "no hazard" supply of 60.

The bulk of the population of Massachusetts is in cities and towns supplied in whole or in part with water from surface supplies —that is, water taken directly from lakes, ponds and streams, or from the impoundments in the form of reservoirs constructed on certain streams. Actually, only a small part of many of these cities and towns is supplied with water from the public supply, and in many of the municipalities water is supplied in part from the ground. If we were

to assume that in the next 60 years the population of the state that would be supplied from surface sources would be equal to that of the 1950 Census of the state, then we should have to agree that if the average daily per-capita water consumption was as great as 100 gal, a total average daily consumption of over 471 mil gal would be the demand. We should also have to agree that if the surface-water sources furnishing this water were so developed as to provide storage of only 200 mil gal per square mile of drainage area, about 600 sq mi of drainage area would require some form of protection. I agree that that is a lot of water and also a lot of drainage area, but when one considers the present problems of water supply facing the city of New York in the easterly part of the country and the Los Angeles district in the westerly part of the country, our assumptions as to possible future requirements of this state do not loom up quite so large. Very few areas in Massachusetts outside of the drainage areas of the Boston Metropolitan Water District or the Springfield Water Supply could be economically developed for large storage facilities. Because of the density of the population of Massachusetts, the problem of supplying a population of nearly 5,000,000 from surface sources in the future would be very great.

According to the United States Census, Massachusetts has a land area of 7,838.7 sq mi, but an examination of the topographic maps of the state will show that about 1/3 of this area, or about 2,537 sq mi, constitutes what is known as the coastal plain. This coastal area, which is in the easterly part of the state, cannot be developed for surface-water collection.

At this point it might be well to explore the surface-water possibilities of a state like Massachusetts and then to examine what has been set up as "good practice" in water-supply protection.

Surface-Water Supplies

A table contained in Massachusetts Legislative Document #1300 of 1934 (page 12) shows by counties the number and area of lakes, ponds and reservoirs in the state with areas in excess of ten acres and, therefore, in some cases termed "great ponds" or the property of the people (Table 1).

It will be seen from Table 1 that about 26.4% of the pond area

TABLE 1.—NUMBER AND AREA OF GREAT PONDS AND RESERVOIRS IN VARIOUS COUNTIES IN THE COMMONWEALTH OF MASSACHUSETTS†

County	Ponds ten or more acres in area				
	Total		Used for water-supply purposes		Per cent of area used for water-supply purposes
	Number	Area in acres	Number	Area in acres	
Barnstable	164	9,452	1	150	1.6
Berkshire	61	5,848	6	377	6.4
Bristol	81	8,156	3	2,254	27.6
Dukes	25	3,998	—	—	—
Essex	71	5,059	24	2,954	58.3
Franklin	26	1,132	2	106	9.4
Hampden	50	3,670	5	803	21.8
Hampshire	33	1,535	2	71	4.6
Middlesex	136	9,734	21	3,666	37.7
Nantucket	6	812	+1*	+6	0.7
Norfolk	73	4,578	4	573	12.5
Plymouth	178	16,607	15	6,797	40.9
Suffolk	5	252	1	123	48.8
Worcester	306	26,706	45	7,899	29.6
Total	1,215	97,539	129	25,773	26.4

*Emergency only.
†From Massachusetts Legislative Document #1300 of 1934 (p. 12).

of the state (ponds over ten acres in area) is used for water-supply purposes; accordingly, it should be mentioned that an examination of the other 73.6% of the pond area would show use to a highly developed degree for resort and recreational purposes, which are large sources of revenue to the Commonwealth of Massachusetts.

A very excellent study of the water resources of Massachusetts, their conservation and utilization, was made by a Massachusetts Commission on Waterways and Public Lands in existence in the year 1918. In that report are set forth the drainage areas of the various rivers of the state, both intrastate and interstate. That report was published as Senate Document #289 of the year 1918. In order to show a comparison of the drainage areas of our various river valleys, contained within the boundaries of the state, as compared to the areas tributary to these streams before they enter the state, Table 2 is presented.

TABLE 2.—RIVER VALLEYS AND THEIR DRAINAGE AREAS LYING WITHIN MASSACHUSETTS OR TRIBUTARY TO MASSACHUSETTS

Name of river	Total drainage area (sq mi)	Square-mile area In Mass.	Square-mile area Above Mass.	Per cent of total area In Mass.	Per cent of total area Above Mass.
Merrimack	5,015	1,200	3,815	24	76
Connecticut	11,345	2,720 (Rough Est.)	7,195	24	63+
Millers[1]	394	344	50	87	13
Deerfield[1]	665	About 425	240±	64	36
Chicopee[1]	721	721	None	100	None
Westfield[1]	515	About 500	Small	97±	Small
Farmington[1]	600	121	Cons.	20±	Cons.
Housatonic	1,930	532**	45	27	2
Hoosick	710	204	40	29	6
Quinebaug	725	163	‡	22	Cons.
French	112	93	—	83	—
Blackstone	475	311	‡	65	Cons.
Nashua[2]	530	440†	Cons.	83	Cons.
Concord[2]	405	405	None	100	—
Shawsheen[2]	75	75	None	100	—
Powow[2]	51	15—	36+	29	71
Spicket[2]	78	10	68	13	87
Ipswich[3]	147	147	None	100	—
Charles (at Watertown Dam)[3]	270+	270+	None	100	—
Neponset[3]	114*	114*	None	100	—
Taunton[3]	529	529	None	100	—

[1]Tributary to Connecticut.
[2]Tributary to Merrimack.
[3]In coastal plain.
*Receives drainage of about +66.7 sq mi of Charles.
**Above Massachusetts—Connecticut boundary.
†Entering New Hampshire from Massachusetts.
‡Considerable entering Massachusetts from south.

It will be seen from Table 2 that the drainage areas of the two largest interstate streams entering Massachusetts—viz., the Connecticut and the Merrimack Rivers—comprise a total of about 11,010 sq mi, as compared to only 3,920 sq mi of drainage area which are located within the state. In other words, of the 14,930 sq mi of water-

shed of these two rivers contributing water to Massachusetts, only about 3,920 sq mi can be protected by action of Massachusetts alone, and that Commonwealth must depend upon the exercise of Federal Acts or interstate compacts to protect the runoff from the other 11,010 sq mi. Since Massachusetts in future years might possibly require at least 600 sq mi of drainage areas to satisfy its surface water-supply demands, it is quite possible that it may have the problem of depending upon the runoff from outside drainage areas and of determining the extent to which these areas should be protected.

Recommended Water-Sanitation Practice

Water-sanitation practice has been pretty much established by the United States Public Health Service, inasmuch as that service has general power of approval of the quality of water to be supplied on common carriers in interstate traffic. It is to be expected that in the future most of the large municipal water supplies will fall within this category. For this reason alone, any state must be protected from the pollution from another state, at least to the extent provided in Section 2 of Public Law 845 of the 80th Congress, which provides in part that:—

> ". . . The pollution of interstate waters in or adjacent to any State or States (whether the matter causing or contributing to such pollution is discharged directly into such waters or reaches such waters after discharge into a tributary of such waters), which endangers the health or welfare of persons in a State other than that in which the discharge originates, is hereby declared to be a public nuisance and subject to abatement as herein provided. . . ."

The protection offered by this Federal act and the protection which is provided under Article VI of the compact* executed by the New England Interstate Water Pollution Control Commission are not enough to assure of water's being supplied within the requirements of the United States Public Health Service. These requirements read in part as follows:—

> "As to the source and protection the water supply shall be:
>
> (a) Obtained from a source free from pollution; or

*Each of the signatory states pledges to provide for the abatement of existing pollution and for the control of future pollution of interstate inland and tidal waters, as described in Article I, and to put and maintain the waters thereof in a satisfactory condition consistent with the highest classified use of each body of water.

(b) Obtained from a source adequately purified by natural agencies; or
(c) Adequately protected by artificial treatment.

The water supply system in all its parts should be free from sanitary defects and health hazards, and all known sanitary defects and health hazards shall be systematically removed at a rate satisfactory to the reporting agency and to the certifying authority. . . . Approval of public water supplies by the reporting agency and the certifying authority will be conditioned by the existence of:

(a) Rules and regulations prohibiting connections or arrangements by which liquids or chemicals of unsafe, unknown, or questionable quality may be discharged or drawn into the public water supply;
(b) Provisions to enforce such rules and regulations effectively on all new installations; and
(c) A continuing program to detect health hazards and sanitary defects within the water distribution system. . . ."

Under the provisions of Public Health Bulletin #296 of 1946, the United States Public Health Service offers the following as "defects" to be considered in "Water-Sanitation Practice" for surface supplies:

"Examples of Sanitary Defects, Surface-water Supplies, Unfiltered

1. Absence, or inadequacy, of chlorination, or lack of proper control of chlorination; insufficient contact period when chloramines only are present in treated water.

2. No restrictions on recreational use of streams and reservoirs, together with their marginal lands, in the local catchment area.

3. Existence of sources of pollution, such as population on watershed, lumbering, hunting, grazing, and other activities; leaching cesspools, or sewers draining into streams or lakes of the catchment area, or into the marginal lands adjacent to them.

4. Improper location of intake with respect to bottom of reservoir and current, or to surface-drainage-water inlets.

5. Intake exposed and accessible to trespassers.

6. For lake supplies: Vessels passing near intakes; drift of ice fields; dumping of dredgings, garbage, etc., into lake near intakes; inadequate toilet facilities."

"Surface-water Supplies, Filtered

1. Excessive raw-water pollution in relation to extent of treatment provided (see Sec. II, A, 1., p. 6); existence of nearby uncontrolled sources of raw-water pollution.

2. Bypass connections for raw water, or partially treated water, whereby such waters may be discharged into the distribution system.

3. Existence of cross-connections, bypasses, or concrete channel walls within the plant, such as between conduits or basins carrying untreated or partly treated water, and those containing completely treated water.

4. Lack of reserve capacity of treatment works, necessitating excessive overloading, or occasional bypassing of units.

5. Lack of competent supervision and operation, or of adequate laboratory control (part II, C, 2).

6. Deficient or inaccurate operation or laboratory records (part II, C).

7. Lack of suitable devices for measuring and recording volumes of water treated; for maintaining continuity of coagulant and chlorine dosage; deficient retention periods in settling basins (part II, B, 4); or areas, depths, sizes of sand and washing facilities for filters.

8. Lack of or deficiency in proper chlorination equipment and control, or failure to maintain proper chlorine residuals in the treated effluent at all times.

9. Lack of suitable protection for purified water; storage capacity less than requirements for safety.

10. Improper location of water-treatment plant or inadequate protection with respect to flood waters."

Attention is called to the almost complete absence of watershed protection where treatment works are.

Difficulties of Watershed Protection

During 1936 and 1937, a special joint commission, consisting of the Metropolitan District Water Supply Commission and the Department of Public Health, made what was probably the most complete sanitary survey with statistical analyses that has ever been made in connection with a large drainage area, tributary to a public water supply in Massachusetts. This survey was made under the direction of George W. Coffin, then sanitary engineer with the Metropolitan District Water Supply Commission. The report of the commission which includes the results of the survey has been published as House Document No. 262 of the Massachusetts Legislature of 1938.

This survey covered nearly 500 sq mi of drainage area of the principal sources of the Metropolitan Water Supply and included consideration of nearly every variety of real or potential sources of pollution. The results of this survey are tabulated in the following table:—

1. Drainage area (square miles)	74.66	117.04	96.8	185.9	474.40
2. Population					
Permanent	25,999	8,723	3,277	1,451	34,450
Summer or seasonal	296	1,180	950	266	2,692
Population (permanent) per sq mi	348	74.5	33.9	7.8	83.3
Per cent of permanent population in sewered area	65.2	6.5	21.3	—	—
3. Livestock					
Horses	337	465	207	138	1,147
Cattle	2,955	2,950	1,474	1,088	8,467
Swine	1,077	1,365	201	152	2,795
Sheep and goats	162	51	35	63	311
Poultry	69,059	58,785	54,626	19,320	201,790
Dogs	1,264	1,130	458	199	3,051
4. Water supply, number of premises having public supply	4,356	675	154	—	5,215
Private supply (usually from well)	663	1,483	712	466	3,324
No, or an unknown, supply	286	317	130	78	811
Per cent of premises having public supply	82.4	28.0	15.5	—	56.2
5. Sanitary facilities of premises					
Public sewer	2,650	—	—	—	2,650
Flush closets and cesspools, septic tanks	2,040	1,649	331	181	4,201
Privies	424	672	561	299	1,956
Cesspools for sink wastes only	159	355	170	65	749
No; or an unknown facility	247	195	130	71	643
Per cent of premises connected to public sewer	49.7	—	—	—	28.6
6. Number of premises examined					
Residential	4,445	1,983	709	368	7,505
Agricultural	167	174	132	71	544
Business and industrial	265	41	10	3	319
Institutional	52	38	18	19	127
Miscellaneous	406	239	127	83	855
Total	5,335	2,475	996	544	9,350
7. Total unsatisfactory sanitary facilities or conditions	332	506	393	154	1,385
8. No. of premises having unsatisfactory sanitary conditions	242	385	284	89	1,000

Similar surveys were made of all industries on these watersheds.

It will be seen from the above table that at the time of the sanitary survey, there was a considerable number of possible sources of pollution to the Metropolitan Water Supply and many potential sources of pollution. These conditions were found to exist in spite of the fact that regular and careful inspections are made of the watershed, and in spite of the fact that the Metropolitan Water District owns vast areas of land which have been acquired for more adequately protecting its water supply from pollution, and in spite of the fact that regulations* having the force of law have been adopted for assisting in preventing the pollution of its sources of water supply and their tributaries and the acquisition by private agencies of vast areas of land set aside as public or semi-public reservations.

There follows a description of the above areas and control and inspection data:

METROPOLITAN DISTRICT COMMISSION WATERSHEDS

	Total area (sq mi)	Area owned by M.D.C. (sq mi)
Cochituate	17.4	*
Sudbury	75.2	**
Wachusett	107.7	15.6
Quabbin	185.9	126.5
Ware River (Shaft 8)	98.0	33.0

*Cochituate is now under control of the Massachusetts Department of Conservation.
**Ashland and Hopkinton Reservoirs also have been turned over to the Massachusetts Department of Conservation.

The Water Division of the Metropolitan District Commission employs approximately 14 men who take samples of the water at various points, analyze the samples, supervise and control chlorination, supervise and control sanitary conditions in the drainage areas and are generally responsible for the quality of the water. They are employed at the three division laboratories, located at Boston, Framingham and Quabbin.

The writer makes no effort to determine the value of the land thus acquired and set aside as public or semi-public water-supply domains, but if only that land acquired by the Metropolitan District Commission is taken into consideration, this represents a very considerable capital investment. Similar comment could, of course, be made

*Copy of regulations appended.

concerning land acquisitions and costs of inspection of other large watersheds in Massachusetts, such as those in use by the cities of Pittsfield, Springfield and Worcester.

In commenting upon a questionnaire sent out by the American Water Works Association, I stated in 1948, relative to surface-water supplies, that:—

> "There is only one source of water supply in Massachusetts which is taken from a source known to be polluted, viz., the City of Lawrence, which receives the sewage from the larger municipalities in Massachusetts and New Hampshire upstream from the City of Lawrence.
>
> ". . . the surface water supplies in Massachusetts are provided with adequate treatment.
>
> "The water purification systems in Massachusetts are operated satisfactorily, with the exception of one iron removal plant which, however, does not present a health hazard.
>
> "It is my opinion that salaries customarily offered to water works personnel are not sufficient to attract sanitary engineers to such positions, and it is my further opinion that the sanitary engineering training is a valuable asset to the New England Water Works Superintendent."

The Public-Health Hazard

In view of the requirements of watershed protection, it might be well to explore the public-health hazard, as it existed in connection with public water supplies in 1946, as compared with 1914.

In the year 1914 the Massachusetts case rate for typhoid fever was about 64 per 100,000, and during the year 1946 it was 0.73 per 100,000. Therefore, so far as the typhoid-fever case rate is concerned, it would appear to be fair to ask ourselves . . . "are we becoming too *increasingly* rigid in connection with the protection of our water supplies?"

Harold A. Thomas, Jr., Associate Professor of Sanitary Engineering in the Harvard Graduate School of Engineering, has made a careful mathematical analysis of the probability of the contraction of typhoid fever from public water supplies in Massachusetts. The following constitutes his conclusion from this analysis:

TABLE V[1]

Probability of Contraction of Typhoid Fever from Public Water Supplies in Massachusetts Relative to the Probability in 1925

Year	Population	% population served by public supplies	Typhoid morbidity rate per 100,000	Observed average coliform density, organisms per 100 ml	Permissible** coliform density, organisms per 100 ml	Typhoid probability based on Observed coliform density	Typhoid probability based on Permissible coliform density
1914	3,639,803	65	63.4	——	2.23	——	4.3
1925	4,143,724	75	13.7	0.95	1.05	1	1
1946	4,567,621	95	0.65	0.27	1.05	0.070*	0.24

$$*0.070 = \frac{(0.65)^{0.461} \times 0.27}{(13.71)^{0.461} \times 0.95}$$

**Drinking Water Standards: permissible coliform density $= 2.3\ (10)\ \log \frac{1}{1-p}$

where p = proportion of 10-ml tubes permitted to be positive.

"*Conclusion*: The implication of the result shown in the last column in Table V is that water supplies in 1925 had about four times the capacity for transmitting typhoid that water supplies with the same coliform density have today. Yet it is manifest that the 1925 standard was a safe standard: in compliance with it the number of typhoid cases traceable to water supplies became vanishingly small. Under present conditions the same degree of safety could be attained by relaxing the standards so as to permit 35% of 10 ml tubes to be positive."

In this same paper I stated that Allen Hazen recorded as early as 1907:

". . . It is often impossible to remove population from a catchment area, and in fact, it is usually unnecessary to do so. Very good water is drawn from areas upon which there is much population when proper and well-known precautions are taken. . . .

". . . the influence of the population upon the quality of the water in the future will be less than it now is, because it now seems clear that in order to improve the physical character of the water . . . the water of these reservoirs is sure to be subjected to some process of purification before delivery and when this is done such effects of pollution as there may be will be largely removed at the same time and by the same means. . . ."

[1]Paper by A. D. Weston, entitled "Is There Much of Anything Wrong with Our Public Water Supply Control?", presented to American Water Works Association on June 1, 1949.

Summary

As briefly as possible, I have tried to bring to your attention certain problems in the procurement and maintenance of surface-water supplies, more especially in the Commonwealth of Massachusetts.

Problems resulting from increased density of population have been indicated and how those problems were given recognition as early as 1927 by a committee of this Association.

The problem of obtaining additional water supply from surface sources in Massachusetts has been emphasized and mention could have been made of the problem, already facing certain sections of the State of Rhode Island, which it has been the writer's privilege to investigate in recent months.

In connection with the lakes and ponds of Massachusetts, it has been pointed out that over 26% of the pond area of the state has been set aside for water-supply purposes and that vast areas have been acquired and restricted in use for the protection of these public water supplies; yet from a statistical probability analysis we must admit that the danger of infection from water-borne diseases appears to be diminishing rather than increasing. Mention has been made of the increased demands for supplying a safe water in spite of this lessening danger from such diseases.

Finally, I have called your attention to certain factors of safety from pollution of our streams by reference to a Federal Water Pollution Act and the existence of a New England States compact, aimed towards better water-pollution control.

This paper might well have been summarized with the statement that the writer believes that we in New England have obtained our surface public water supplies in the past in "the easy way" and that in the not-distant future they must be obtained in "the hard way."

In the past we did not have to contend with the dense populations which we face in the future, nor did we have the problem of greater use of waterways for recreation or the increased problems of sewage disposal in the rural areas, due to modern plumbing practices.

In the past we have gone "to the hills" for our waters, but in the future we shall have to look to our valleys.

In the past there was not the demand to use every lake, pond or

stream for bathing, boating, fishing and other forms of recreation, but in the future these demands will increase rather than decrease.

In the past we had numerous potential sources of supply, free of sewage or sewage effluent, but in the future such sources will be harder to find and maintenance will be more difficult. We shall be faced with the problem which our brothers in the water-works field of the middle west have faced over a number of years—that is, to take these sewage-polluted waters and make them safe for drinking.

Just how far we can go in the future in the acquisition of lands for the protection of our water supplies is problematical. Land increases in value as density of population increases.

Just how far we can withstand public pressure to use our waterways for recreation also is problematical. As public servants you water-works officials have indeed an exceedingly difficult job in this respect.

Frankly speaking, we have about reached the crossroads between *over*-protection of our water supplies and *under*-protection. In my opinion, a far greater number of water-treatment plants will be seen in the future per million gallons of water delivered than we have seen in the past.

Appendix

Sanitary Rules and Regulations for the Metropolitan Water Supply The Commonwealth of Massachusetts

Office of State Department of Public Health, State House

Boston, July 8, 1948

Rules and Regulations of the State Department of Public Health Adopted by Said Department for the Sanitary Protection of Waters Used by the Metropolitan District Commission for the Water Supply of Any Town or Water Company under the Authority of Chapter 92 of the General Laws, Chapter 375 of the Acts of 1926 and Chapter 321 of the Acts of 1927

The State Department of Public Health, acting under the authority of section 17, of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, hereby makes the following rules and regulations for the sanitary protection of all waters used by the Metropolitan District Commission for the water supply of any town or water company, under the Authority of said General Laws, chapter 375 of the Acts of 1926 and chapter

321 of the Acts of 1927 and which shall remain in force until further order, and which may be hereafter from time to time amended or added to by the Department of Public Health.

The provisions of the following rules and regulations, so far as they are the same as those of the existing rules and regulations, shall be construed as a continuation thereof and not as new provisions.

The rules and regulations adopted by the State Department of Public Health under date of June 16, 1925 are hereby repealed.

Rules 14 and 15 of Rules and Regulations adopted on July 9, 1940, amended by vote of Public Health Council on July 8, 1948.

1. No cesspool, privy, or other place for the reception, deposit, or storage, of human excrement, and no urinal or watercloset not discharging into a sewer, shall be located, constructed, or maintained, within 50 feet of high-water mark of any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, or within fifty feet of high-water mark of any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said Commission.

2. No human excrement shall be deposited or discharged in or into any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, or into any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said commission; and no human excrement shall be kept in or deposited or discharged in or into any cesspool, privy or other receptacle, situated within two hundred and fifty feet of high-water mark of any open waters so used by said commission, or within two hundred and fifty feet of high-water mark of any open waters flowing as aforesaid into waters so used by said commission, unless such cesspool, privy, or other receptacle, is so constructed that no portion of its contents can escape or be washed into any such waters.

3. No human excrement, or compost containing human excrement, or contents of any privy or cesspool or sewer or other receptacle for the reception or storage of human excrement, shall be deposited or discharged upon or into the ground at any place from which any such excrement, compost, or contents, or particles thereof, may flow or be washed or carried into any lake, pond, reservoir, stream, ditch, water course, or other open waters used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the

Acts of 1927, or into any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said commission.

4. No house slops, sink waste, water which has been used for washing or cooking, or other polluted water, shall be discharged into any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, or into any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said commission; and no house slops, sink waste, water which has been used for washing or cooking, or other polluted water, shall be discharged into the ground within fifty feet, or upon the ground within two hundred and fifty feet, of high-water mark of any open waters so used by said commission, or into the ground within fifty feet, or upon the ground within two hundred and fifty feet, of high-water mark of any open waters flowing as aforesaid into waters so used by said commission.

5. No garbage, manure, or putrescible matter whatsoever, shall be put into any lake, pond, reservoir, stream, ditch, water course, or other open waters used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, or into any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said commission; and no garbage, manure, or putrescible matter whatsoever, shall, except in the cultivation and use of the soil in the ordinary methods of agriculture, be put upon the ground within two hundred and fifty feet of high-water mark of any open waters so used by said commission, or within two hundred and fifty feet of high-water mark of any open waters flowing as aforesaid into waters so used by said commission.

6. No stable, pig-sty, hen-house, barnyard, hog-yard, hitching or standing place for horses, cattle, or other animals, or other place where animal manure is deposited or accumulates, shall be located, constructed, or maintained, any part of which is within fifty feet of high-water mark of any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, or within fifty feet of high-water mark of any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said commission; and no stable or other place, as above enumerated, shall be located, constructed, or maintained within two hundred and fifty feet of high-water mark of any open waters flowing as

aforesaid into waters so used by said commission, unless suitable and adequate provision is made to prevent any manure or other polluting matter from flowing or being washed into such open waters.

7. No interment shall, except by permission in writing by the Metropolitan District Commission, be made in any cemetery, or other place of burial, within fifty feet of high-water mark of any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by said commission for the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, or within fifty feet of high-water mark of any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said commission.

8. No lands, which were not under the control of cemetery authorities and used for cemetery purposes on July 1, 1899, from which the natural drainage flows into any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, or into any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said commission, shall be taken or used for cemetery purposes until a plan and description of the lands which it is proposed to use for such purposes, sufficient for their identification, shall be presented to the State Department of Public Health, and until such taking or use shall be approved in writing by the State Department of Public Health.

9. No manufacturing refuse or waste product or polluting liquid or other substance of a nature poisonous or injurious either to human beings or animals, or other putrescible organic matter whatsoever, shall be discharged directly into, or at any place from which it may flow or be washed or carried into, any lake, pond, reservoir, stream, water course, or other open waters used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, or into any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any waters so used by said commission.

10. No system of sewers or other works for the collection, conveyance, disposal, or purification, of domestic or manufacturing sewage or drainage, or any other putrescible organic matter whatsoever, shall, except in accordance with plans first approved in writing by the State Department of Public Health, be constructed or maintained at any place within the watershed of any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the

provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927. No private or separate sewer shall be constructed or maintained having an outlet upon or in the ground within two hundred and fifty feet of high-water mark of any open waters so used by the Metropolitan District Commission, or within two hundred and fifty feet of high-water mark of any lake, pond, reservoir, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into any water so used by said commission.

11. No public or private hospital, or other place intended for the reception or treatment of persons afflicted with a contagious or infectious disease, shall, until the location and construction thereof have been approved in writing by the State Department of Public Health, be located or constructed at any place within the watershed of any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927. No public or private hospital, or other place intended for the reception or treatment of persons afflicted with a contagious or infectious disease, shall be maintained at any place within such watershed, unless all the provisions required by the State Department of Public Health for the purification or disposal of sewage, drainage, or other polluting or organic matter, which may be discharged therefrom, have been complied with, and unless all orders issued from time to time by the State Department of Public Health in relation to the purification and disposal of sewage, drainage, and other polluting or organic matter, which may be discharged therefrom, are fully complied with.

12. No tannery, currying shop, or other establishment or place where the skin, wool, hair, or fur, of any animal is treated, shall, until the location and construction thereof have been approved in writing by the State Department of Public Health, be located or constructed at any place within the watershed of any lake, pond, reservoir, stream, ditch, water course, or other open waters used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927. No tannery, currying shop, or other establishment or place where the skin, wool, hair, or fur, of any animal is treated, shall be maintained at any place within such watershed, unless all the provisions required by the State Department of Public Health for the purification or disposal of sewage, drainage, and other polluting or organic matter, which may be discharged therefrom, are fully complied with.

13. No slaughterhouse or other building for carrying on the business of slaughtering cattle, sheep, or other animals, and no melting or rendering establishment, shall, until the location and construction thereof have been approved in writing by the State Department of Public Health, be located or constructed at

any place within the watershed of any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927. No slaughter-house or other building for carrying on the business of slaughtering cattle, sheep, or other animals, and no melting or rendering establishment, shall be maintained at any place within such watershed, unless all the provisions required by the State Department of Public Health for the purification or disposal of sewage, drainage, or other polluting or organic matter, which may be discharged therefrom, have been complied with, and unless all orders issued from time to time by the State Department of Public Health in relation to the purification and disposal of sewage, drainage, and other polluting or organic matter, which may be discharged therefrom, are fully complied with.

14. No person shall wade or bathe in, and no person shall, unless permitted by special regulation or by a written permit of the Metropolitan District Commission, fish in, or send, drive, or put, any bird, fowl or animal into Quabbin Reservoir, the Intake Reservoir on the Ware River at Coldbrook, the Wachusett Reservoir, so called, the open channel of the Wachusett Aqueduct, Sudbury Reservoir, Framingham Reservoir Number 3, Spot Pond, Chestnut Hill Reservoir, or any other lake, pond, reservoir, aqueduct, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927. No person other than a member of the said Metropolitan District Commission, its officers, agents, or employees, or public officers whose duties may so require, shall, unless so permitted by regulation or permit of the said commission, enter or go, in any boat, skiff, raft, seaplane or other contrivance, on or upon the water of any of said reservoirs, or said pond, or open channel, or of other such lakes, ponds, reservoirs, or streams, nor shall enter or go upon, or drive any animal upon, the ice of any of said waters or other such lakes, ponds, reservoirs, or streams.

15. No person shall enter upon the Quabbin Reservoir, the Intake Reservoir on the Ware River at Coldbrook, the Wachusett Reservoir, so called, the open channel of the Wachusett Aqueduct, Sudbury Reservoir, Framingham Reservoir Number 3, Spot Pond, Chestnut Hill Reservoir, or any other lake, pond, reservoir, aqueduct, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission as a source, or for the conveyance, storage, or distribution, of the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, for the purpose of cutting or taking ice, or cut or take ice from any such lake, pond, reservoir, aqueduct, stream, ditch, water course, or other open waters, without a written permit granted by said commission, stating the time and place for which such permission is given.

16. All reports which may be made to any board of health, or to any health officer of any city or town, of cases of contagious or infectious diseases occurring within the watershed of any lake, pond, reservoir, stream, ditch, water course, or other open waters, used by the Metropolitan District Commission for the water supply of any town or water company, under the provisions of chapter 92 of the General Laws, chapter 375 of the Acts of 1926 and chapter 321 of the Acts of 1927, shall be open to the inspection at all reasonable times of said commission, its officers or agents.

By order of the State Department of Public Health.

Discussion

Warren J. Scott (Hartford, Conn.). In his paper, Mr. Weston emphasizes some of the problems facing water-works and public-health officials in connection with the growing demands for water supply for our urban communities on the one hand, and for recreational and possibly additional uses of the waters of our streams and ponds on the other. It is difficult to attempt to lay out a perfectly charted course and Mr. Weston has not tried to do this.

The history of reduction in water-borne disease in New England is one of which water-works and public-health officials can be proud. Our New England States have stood in the forefront in the war upon water-borne typhoid fever and other intestinal disease caused by water. With few exceptions our main line of defense in New England has been the relatively clean condition of our sources of supply. Within the past two or three decades, chlorination has been added to our safeguards, so that today there are relatively few surface-water supplies not protected by chlorination against chance contamination. In Connecticut, we have today only one public water supply, furnishing water to about 30 families, which supplies unchlorinated surface water, and this company is now planning on a chlorinator installation. We have 134 chlorination plants on our 107 public water systems, several systems maintaining more than one chlorinated surface source. Of our 107 public water systems, 57 secure their water from surface sources, 32 from ground-water sources and 18 from a combination of the two.

The installation of filtration plants has proceeded at a much slower pace. We have only 27 filtration plants on our Connecticut public water supplies. With but two or three exceptions, these filter plants were built primarily to handle color and taste and odor difficulties,

rather than for reduction of bacteria, even though they do incidentally and desirably constitute a great additional safeguard against waterborne disease.

In the past decade or two, we have seen increasing development of our ground-water supplies, especially for smaller cities and towns. While these are mostly on systems supplying populations in the 1,000 to 10,000 population range, a certain number of auxiliary ground-water supplies of substantial yield have been developed in larger communities. Some areas of our state with underlying sand and gravel have been successfully tapped for good yields of water and considerably more ground-water development would seem to be in prospect. The development of these supplies will lessen some of the pressure for surface-water sources in the future.

Many of our present watersheds on public water supplies will support large increases in storage through new or enlarged reservoirs on these same watersheds, substantial increases in water yield being thus provided without putting new watersheds into use. In recent years, the tendency has been to acquire land for reservoir sites and reservoir shore-line protection, but not to purchase land in substantial amounts on upper streams. Our sanitary engineers make inspections of dwellings on public watersheds about once in every one or two years. Some of these watersheds are fairly densely populated. These visits and the inspections of water-works employees are of tremendous benefit in eliminating sewage pollution of tributary streams, as well as in promoting good sanitary standards on the watersheds for the protection of the watershed residents themselves. An overflowing cesspool not only may pollute the water-supply stream, but may create possibilities of fly-borne infection of the family of the owner of the cesspool.

As an example of a program of education and coöperative effort, one of the sanitary engineers of the Connecticut State Department of Health recently completed a sanitary survey of one of our most heavily populated watersheds, supplying water to an estimated population of 69,000 persons. He visited 564 properties, which are indicated by number on a watershed map. These were not *all* of the properties on the watershed, but only those near tributary streams and gullies. At but two locations did he find insanitary conditions, that

might cause sewage pollution under certain conditions of run-off and that needed immediate correction. He found some additional locations where he recommended that conditions be kept under surveillance. The watershed was 21.6 sq mi in area. It would seem that the accomplishment of such good sanitation is worthwhile, from the viewpoint of watershed protection and the viewpoint of securing a sanitary environment for the watershed residents. This accomplishment, too, has been secured with a minimum of purchase of watershed properties, most of the water-utility ownership being around the shore line of their reservoirs. The cost, therefore, cannot be considered excessive.

We cannot foresee any over-all acute shortage of water for municipal needs in our state for a good many years in the future, but there will be certain developments and problems that will play an important part in our progress in the water-supply field in the next few decades, such as:

1. The development of additional ground-water supplies.
2. Planning of real-estate developments in unsewered communities, situated on streams that will be used for water supply, so that ample lot sizes will permit adequate sub-surface seepage systems for sewage disposal and thus avoid pollution of streams and creation of nuisances to the property owners themselves.
3. Development of increased storage on existing watersheds within practical limitations, so as to reduce the need for taking additional watershed area for public water supply.
4. Extension of metropolitan water-supply systems to fringe areas needing water, and additional inter-connections between small and large supply systems. Such inter-connections are extremely helpful from the standpoint of national defense. Connections from large systems tend to make unnecessary some developments of watersheds for small communities, when their needs can readily be met by nearby large systems without undue burden upon the systems.
5. Use of interstate streams for water supply, such as we are already using in Connecticut. Some of these streams drain relatively sparsely populated areas in New York State and

Massachusetts. It will probably not be possible to enforce as rigorous standards for watershed sanitation in neighboring states as might be called for within a state, although we have had good coöperation from neighboring state health departments.

6. Recreational demands, such as for bathing, will constantly become more pressing. If protective restrictions are substantially relaxed, additional treatment, such as by filtration, will probably become necessary on many surface supplies which are presently unfiltered. This will add materially to the cost of the delivered water. Filtration will have the advantage of providing water of improved physical quality and, along with chlorination, will safeguard against not only bacterial contamination but other pollution as well. Bathing in reservoirs used directly as sources of supply will undoubtedly continue to be prohibited and any opening-up to recreational use should be under carefully thought-out limitations.
7. Possible use of large streams, such as the Housatonic River, which are now far from grossly polluted during much of their course and which are, in fact, reasonably clean. Such use will have to be accompanied by continued progress in control of sewage pollution, because such rivers receive discharges from numerous small and some fairly large community sewerage systems. Also, water-treatment safeguards will have to be carefully planned. The waters of these large rivers will probably be utilized along with large storage reservoirs, possibly in the valleys of tributaries of the large rivers or in the valleys of nearby watersheds, to which water can be pumped at times of excess flows. Sometimes, this storage may be utilized to furnish additional purification safeguards.

I do not consider that we are overdoing our watershed protection in New England. We should continue to do our best to maintain those high sanitary standards for the water supply and the population living on the watersheds that have contributed so much to our excellent record of freedom from water-borne disease. We shall undoubtedly have to re-evaluate our practices as we progress with our increasing

water-supply demands and our growing quest for recreational use of water. There should be no sudden breakdown in our protective safeguards. Every necessary relaxation should be accompanied by necessary additional safeguards. The cost of these additional safeguards, whether through additional treatment of water or of sewage, as well as provision for our essential needs for new water-supply sources, should be placed in the balance. Also, interstate coöperation, such as through the New England Interstate Water Pollution Control Compact, should be worked out to furnish the best development and use of our water resources.

HAROLD B. SCALES (Portland, Me.). It was with a great deal of pleasure that I read Mr. Weston's paper prior to its presentation here this morning. I believe that all of us, as water-works men, and more particularly those of us who have the responsibility of maintaining the purity of a water supply, have been confronted at some time or other with the same question that serves as the title of his paper, "Sanitary Protection of Watersheds—Are We Overdoing or Underdoing It?"

The State of Maine, not being nearly so densely populated as some of our other New England States—in particular, Massachusetts, Connecticut and Rhode Island—has not therefore as great a watershed-protection problem. For example, Mr. Weston in his paper cited Massachusetts as having a population density of more than 600 per square mile, whereas Maine, with a resident population of approximately 900,000 and an area of approximately 30,000 sq mi, which incidentally is very nearly the size of all the other New England States combined, has, as you will readily see, only about 30 people per square mile. It is true that roughly a million tourists visit the State of Maine from June 1st to October 1st, but even if we included them with the resident population, it would then figure only 63 people per square mile and that would be for only four months out of the year.

It is likewise true that the bulk of the population of Maine is settled in the southern end of the state, which comprises roughly about one-third of the total area. Even on the assumption that all of the population were confined in this southern area, the population density would be only 90 per square mile, or 189 per square mile if we in-

cluded the tourists and assumed they were in the state all at the same time and for all of the year, which of course is far from being the case.

Another factor in Maine's favor relative to the protection of its watersheds is the fact that the watersheds of most of its water supplies lie entirely within the state itself and are not subject to pollution from neighboring states. This being the case, most watershed-pollution problems could be taken care of by the state legislature, without having to invoke the Federal acts relative to the pollution of interstate waters.

Therefore, comparing conditions in Maine with those in Massachusetts—and I assume about the same conditions exist in Connecticut and Rhode Island as in Massachusetts—I can readily see where those states already have a serious problem on their hands in the sanitary protection of their water supplies and one, as Mr. Weston brought out in his paper, that is going to become increasingly greater as time goes on, whereas in Maine we have not begun as yet to feel the impact of thickly settled areas, with the resultant burdens they place upon watershed protection.

As to the question, "Sanitary Protection of Watersheds—Are We Overdoing or Underdoing It?", it would seem to me that the answer to that question can only be furnished by each individual water company. If one were to ask me if the Portland Water District is overdoing or underdoing the protection of its watershed, I should definitely say "No"'. I think what we are doing is ample, as borne out by the results obtained over a period of 30 or more years, and at the same time has not become a burden either from a physical or a financial standpoint. On the other hand, I know of water companies that do nothing or very little to protect their watersheds, due largely, perhaps, to a lack of funds and manpower.

Portland's source of supply is Sebago Lake, a body of water 12 miles long, 5 miles wide at its widest point, and over 300 ft deep in places. Through an act of the state legislature, bathing is prohibited within a radius of two miles from the intake. Nearly all of the shore property within this two-mile area is owned by the Portland Water District and is constantly patrolled. This two-mile area comprises a good part of what is known as the lower bay of the lake and is partially shut off by the natural shape of the lake from the lake proper, with the result that pollution in this area is kept at a minimum. Since

we have a watershed area of over 400 sq mi, an attempt on our part to police or control this area would, I think you will agree, be grossly overdoing it, if not sheer foolishness, in view of the high quality of the water already maintained in the lower bay by our present restrictions.

I have the firm conviction, however, that the average water consumer would rather drink a water that is fairly free from pollution, even in its raw or untreated state, than one that is grossly polluted and then rendered safe for human consumption. Within the past 25 years two bills have been introduced in the state legislature to compel the Portland Water District to relax some of its sanitary restrictions, the last one being introduced at the last session of legislature, and in both instances the bills were reported by the legislative committees hearing them as "Ought Not to Pass" and died there. I mention this merely to show that legislative committees in two instances did not feel that the Portland Water District was overdoing it in the protection of its supply, but rather that the water in the vicinity of the intake should be kept reasonably free from pollution, even though it received treatment later.

As I stated earlier in this discussion, I believe the answer to the question lies entirely with each water company as to whether watershed protection is being overdone or underdone. I can readily see that, in many instances, watershed protection, where it has been properly and conscientiously carried out, has become a tremendous and ever-increasing burden and when that burden becomes so great as to cause undue hardships on a water company, then I am compelled to agree with Mr. Weston that "a far greater number of water-treatment plants will be seen in the future per million gallons of water delivered than we have seen in the past".

EDWARD L. TRACY (Burlington, Vt.). I think I can agree that watershed protection has not been overdone, although one thing I have been thinking about through the papers is that the application of some of the sanitary standards could become pretty academic on some of our small water systems, and my personal opinion is that there should be some balance between watershed protection and water treatment. In our own particular case that means chlorination in most instances.

I was very much interested to hear it said that it actually is a problem for the local water company, the municipality, or the water officials. In many of our water systems I do not believe you can ever attain perfect watershed protection. As an example of that, we have many small systems where, from the analyses made, the percentage of coliform is very high, but it is perfectly obvious that the intakes are so remote on mountain streams that probably the contamination is from wild animal sources. You are certainly never going to be able to keep wild animals out of the watershed area. But the bacteriological condition of some of those waters is not good and we recommend chlorination. Then it comes down to the municipality or owner of the water system. If they know what the recommendations are—that is, that chlorination has been recommended to reduce the coliform—actually it is up to them as to how far they will go. Some of them, of course, are not too willing to put in chlorination. There are many people who still have the idea that mountain brooks are filled with spring water and are therefore pure. Hence I think I can agree with what others have said—that we have not yet overdone watershed protection—but still I keep in mind that the application of sanitary standards could, as I said before, become too academic.

Is there anybody here from the Public Health Service? I do not mean I want to say something which is not so, but I would rather have them here when I say what I am going to. The thing that comes up sometimes on the small water systems is that probably somebody from the Public Health Service looks at the bacteriological record and says that in such-and-such a month and such-and-such a month it exceeded the permissible 10% of coliform organisms. You can't get anybody from the Public Health Service that far back in the woods to make the recommendations. There again it comes back to the owner or the municipality.

I think that we still have a lot to do, but again our problem is to balance watershed protection and water treatment. By "water treatment" I am not referring to complete treatment plants, filtration. We have only a few municipal plants. The largest one in our state takes the water from Lake Champlain, and there is no problem there, because there is a good treatment plant. But our big problem remains the small community, taking water from mountain-stream sources, and

we do not have the situation that Connecticut has, where they say they have all but one of the public water supplies chlorinated. We have a great many that are not chlorinated.

LINN H. ENSLOW (New York, N. Y.). In my early experiences with the State Health Department and then later as the plant operating man, I used to have the idea that B. coli meant everything, but I soon found out, when I went to Panama, that there are other things which mean more than B. coli. We had a water supply in Panama which came from an uninhabited watershed area—a jungle—and these animal coli did not worry me at all. We did chlorinate, of course, and thoroughly, and I used to think just as an insurance policy, so to speak. If the residual chlorine went out—we missed it sometimes—it did not worry me greatly. Then one day we had a tremendous count of 20° organisms on the plate and the chlorinated water was free, as usual. We found a dead Indian not very far from the intake. That fellow had been crocodile hunting and the crocodile beat him to it, because he was not half there when we found him.

I am thinking in terms of what might happen. I still think that every surface-water supply could afford to have a little chlorine. Things happen up there that you never know about until it is too late. Whether it is dead-horse bugs you have, dead-Indian bugs, or dead-rabbit bugs I don't know, but I don't want to drink such water.

E. SHERMAN CHASE (Boston, Mass.). Mr. Weston's paper and the discussion are thought-provoking. This question of watershed sanitation has been discussed in water-works meetings, along with the significance of B. coli—using the old-fashioned term for those bugs—as long as I can remember. Those of you who have heard me talk on the subject know pretty well where I stand. I think we have to realize that watershed-protection practices must of necessity vary with the different parts of the country. Practices which can be adopted fairly generally in New England are absolutely impractical in, say, the Middle West. The practices of the water-works sanitarians here in New England I think have been based very largely upon the practices established by the Massachusetts Department of Public Health and its predecessor, the old Massachusetts Board of Health. I think the validity of those practices in the past is very

well exemplified by the case rates of typhoid fever in Massachusetts, cited by Mr. Weston. I can remember that when I wrote my thesis at M. I. T., I said that a typhoid death rate of 20 per 100,000 indicated a pretty good water supply. The case rate in Massachusetts, as Mr. Weston said, is less than one per 100,000. This shows how the viewpoint of what constitutes the index of a good water supply has changed in the past 100 years, I might say.

Linn Enslow's reference to the dead Indian and what can happen on an uninhabited water supply reminds me of an incident which occurred in the case of a water supply of one of the New England states, which I shall not mention by name. I was on a watershed inspection with the board of water commissioners. The supply was a very small intake reservoir on an upland stream. The question had arisen as to whether the supply should be chlorinated. There was no filtration and no purification. The state health department had urged and recommended chlorination, and the water commissioners did not want to adopt it. They thought that, by getting somebody else in, perhaps they could get a different opinion expressed —which, incidentally, they did not. As we were going over the watershed, we crossed a little bridge over the brook, shortly above the reservoir. We stood on the bridge, discussing the quality of the supply and the necessity of chlorination. One of the water commissioners consistently spat in the stream from which the water supply was taken. Fortunately it was spit and not something else.

WILLIAM W. BRUSH (New York, N. Y.). I shall give you a statement as to what New York does, which is somewhat different from New England practice. First, New York City has not for quite an extended period of years considered treatment of its supply other than chlorination. New York tried about a half century ago to buy the land around the streams in the Croton watershed, which was the major supply of New York City at that time. The legislature of New York State decided, on the basis of the pressure put upon it by the people in Putnam County and Westchester County, that the buying of land should be stopped, and it was stopped. It has not been the policy for many years to buy land beyond that needed around the reservoir, to protect the shores of the reservoir from pollution

and from access by the public, except under regulations set up by the department.

New York was one of the first cities in the country to adopt duplicate chlorination and it depends upon chlorination, together with storage, for the protection of the supply. From the viewpoint of the results obtained, as shown by the health statistics, I think New York has been about as high as any of the cities in the country.

We are not able to prevent bathing in the streams. One of the health commissioners of New York City, some 25 years ago, told us that if we were to arrest people who were bathing in the streams, the health department would take care of the proof in court that such bathing was affecting the water supply detrimentally, to the extent that the court would prohibit the bathing where the city did not own the land. We carried out our part of the contract, but the city health department failed completely in its part of the contract, and the net result was detrimental from the viewpoint of our controlling the watersheds. In New York some of the water is treated with chlorine five times before it reaches the consumer. All of it is treated twice and practically all is treated three times, and each treatment is an effective one.

WATER-SUPPLY DEVELOPMENTS IN THE OTHER AMERICAN REPUBLICS

BY CLARENCE I. STERLING, JR.*

[*Read September 20, 1950.*]

The difficulty in making a selection of a title for a paper as broad as this one comes when you attempt to write it.

There are 20 other American republics in this hemisphere and each one of them is individual as to its natural resources and social, economic, health, and sanitary conditions. We note little idiosyncracies here in our own United States in speech, in viewpoint, in the people from the Middle West, the South, and even New England. In the other American republics you have other factors: the origin of the people themselves, what percentage of the population are pure whites from the Spanish and other European stocks, and what percentage of the population is either pure Indian or a mixture of Indian and white bloods.

In regard to the development of water supply, we find the same variation in conditions. We find that the climate varies from the hot, steaming climate which we associate with the tropics to the cooler temperate climates. In fact, the latter condition predominates in Latin America. We find tremendous river valleys and incredibly stupendous mountain ranges, all within the same country. There are some cities that have water-supply distribution systems serving areas that are 2,000 ft apart in elevation. We also find rainfall conditions that vary greatly; e.g., in the northern part of Chile the rainfall is about ¼ inch in 20 years, whereas, curiously enough, in the southerly part of the same country we find rainfalls as high as 120 inches annually. In the development of water supplies in Latin America the old adage, "Water is where you find it," is never truer. Every conceivable type of source of water supply has been used, from the taking of water from broad rivers to the development of little springs or the installation of deep tubular wells.

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During my residency and on many trips to Latin America, I had occasion to see many types of water-supply systems and I shall confine my remarks to just a few of those systems that I have seen. Where I use examples to point out certain aspects of the development, the reason for using these examples is that statistics are available.

Water-Borne Diseases

In most of the countries the water-borne diseases are among the 10 leading causes of death. Typhoid fever, dysentery and paratyphoids, for example, in Mexico are responsible for over 21% of the causes of death. It has been estimated that in that country 125,000 people die annually of water-borne diseases. When President Miguel Alemán of Mexico came into office, one of the first things he did was to establish a Department of Hydraulic Resources. Surveys showed that only 30.3% of homes had running water and only 6.8% had both running water and sewage-disposal facilities. Similar conditions exist in many of the other countries. However, in Argentina, Chile and Uruguay, it is unusual to find a community of less than 2,000 population without a public water-supply system.

Water Consumption

Surveys made of water consumption, usually in the larger cities, in Latin America indicate per-capita consumptions of 25 to 200 gal per day. As a general rule, however, it was found that, in designing water-supply systems in Latin America, an acceptable figure was 50 gal per day per capita. In the design of the distribution systems themselves, it is found that the design is based primarily upon the domestic consumption requirements. Except in some of the larger cities, very little allowance is made for fire protection in the design of the water system. Curiously enough, studies made in several of the cities contemplating the installation of a water supply or an additional supply did not indicate any great fire losses. I know of one city with a population in excess of 120,000 people without a public water-supply system or a fire department. I know of a second city of 300,000 population that has a public water-supply system but no fire department, and apparently the fire losses were negligible. Many of the other cities, however, do support either a full-time fire department or a combi-

nation of full-time and volunteer fire department, or are entirely on a volunteer basis.

The water pressure in the distribution systems is usually much lower than that found in the United States. However, where no provisions are made in the design of the water mains for fire-protection purposes, there is little additional capacity available for domestic water consumption when the city or town grows. This often results in the practice of supplying water to only parts of the system during certain hours of the day, or of the water taker's installing pumping equipment to pump water from the main into a storage tank on his own premises. This naturally results in great danger of contamination of the water in the distribution systems. We often find, therefore, that the source of supply is a good one and the quality of water is suitable, either with water filtration or disinfection, but that re-contamination occurs in the distribution system.

In many sections of Latin America, particularly in Central America and the west coast of South America, as well as some of the island republics, earthquakes are a common occurrence. This often causes interruption in the water service or results in a large number of leaks in the distribution system, especially in the service connections.

The Pitometer Co. does a considerable amount of work in Latin America in making pitometer surveys, and I recall that, in the case of the city of Guayaquil, the principal seaport of Ecuador, the water service was restricted to some 4 hours daily, with pressure varying from 0 to 10 lb per sq in. After the survey was made and the larger leaks corrected, water was supplied to the city for a period of 16 hours daily, with pressure ranging from 10 to 30 lb per sq in. Even in a city as big as Rio de Janeiro, Brazil, water service is on an intermittent basis to the various sections of the city, particularly in the outlying areas. One of the most important positions in the Rio de Janeiro Water Department is that of Distribution Engineer, who is in charge of valving off various sections of the city during certain hours of the day.

Water Treatment

There are many modern water-treatment plants in Latin America. Some of them have been designed by North American consulting engineers and some by either national engineers or, in a few cases, European engineers. In general, their design follows modern practice, as we know it here in the United States, and the plants are turning out a good-quality water. At some of the plants they do have problems which we do not ordinarily consider in our own practice; e.g., in the city of La Paz, Bolivia, there is a modern water-filtration plant of the rapid-sand type, with chlorination of the filtered water. However, for no good reason that I could fathom, there is an import duty, equivalent to $75 United States money, on each 100-pound cylinder of chlorine gas imported into the country.

Management

Here again we have a variety of types of management. In some countries the supplies are municipally owned, but in the majority of the countries the practice is for the national government to finance, construct and maintain the public water-supply system. Numerous cities are served by water companies having foreign capital, principally English or United States.

There are many advantages and disadvantages in the national government's operating and maintaining the water-works system. In the first place, there is usually a limited amount of funds available in the national budget for water-works construction; therefore, the community that is able to exert the greatest political influence receives preference. In addition, the installation of a public water system in a town does not always reduce as much as anticipated the death rate from intestinal water-borne diseases. This is due primarily to the fact that, when the government does its own construction and design, there is no other governmental agency to supervise the sanitary quality of the water. Here in the United States the various state departments of public health, through their sanitary engineering divisions, have been largely responsible for communities' installing safe water supplies and maintaining them in that manner. There is a great advantage in the nationalized system, however, when you consider that there is a lack of sufficient sanitary engineers available in the countries. There-

fore, by having a national office, they are able to corral all of the available technical men and make their services and knowledge available to all of the communities, instead of a limited few.

Water-Works Materials and Equipment

Prior to World War II a great part of the water-works materials and equipment was supplied to the other American republics from European sources, with the possible exception of those countries in the Caribbean area which were under the influence of the United States. Naturally these latter countries were in the United States market. Since World War II began, there has been a greater influx of U. S. equipment into those countries. The only restriction upon the amount of equipment sold has been dollar shortages in some of the countries. This has led to the development of local manufacturing of equipment or the importation of materials from European countries that are under the E.C.A. plan. My experience, however, has been that the Latin-American water-works operators and engineers prefer the U. S. equipment and materials, if they can get them at a reasonable price. In many cases they are willing to pay even more than the cost of European equipment to get the material they prefer; however, there is a certain limit beyond which they cannot go, for economic reasons.

In some of the countries, since the end of World War II local manufacturing has been developed. Mexico and Brazil are producing their own cast-iron pipes. Chile, with its tremendous copper resources, is now producing copper tubing. Valves and fittings are also being produced in Brazil. Some fittings are being manufactured locally in Argentina at the present time.

Since 1942 the Institute of Inter-American Affairs, in its good-neighbor program, has done much to stimulate the improvement in the water-supply systems in the Latin-American countries. Furthermore, its programs have brought many of the Latin-American engineers to the United States for graduate study. In addition, the Institute did the major part of the work in helping to organize the Inter-American Association of Sanitary Engineering. Your Water and Sewage Works Manufacturers Association gave a tremendous amount of help in the development of that Association, both morally and financially.

I know that a number of members of the New England Water Works Association have assisted in the development of water supplies in Latin America; e.g., Peter C. Karalekas, Chief Engineer for the Springfield (Mass.) Water Department, designed and constructed the water-filtration plant in Tegucigalpa, the capital of Honduras; James L. Dallas, Assistant Sanitary Engineer in the Massachusetts Department of Public Health, constructed several water-treatment plants and water systems in Venezuela and Costa Rica; H. L. Field, Superintendent of the Water Department in Greenfield, worked with the Venezuelan national government to install good water-works practice in the Caracas Water Department; Wyman Stone of Athol, Mass., who used to be associated with the Connecticut Health Department, worked on construction of the Bogota, Colombia, water-treatment plant, one of the most beautiful and efficient water-treatment plants that I have seen. In addition, he designed and constructed some 15 water systems in Mexico and Ecuador. Frank Blaisdell, formerly Assistant Sanitary Engineer in the Maine Health Department, designed two water systems in Bolivia. There are many others, too numerous to mention at this time.

I do hope that all the members of this Association will always have their latch-strings outside of the door to any of their brother water-works engineers from the other American republics who so earnestly desire to utilize your information and experience.

THE CONSTRUCTION OF SPHERICAL AND RADIAL-CONE ELEVATED TANKS

BY J. E. REVELLE*

[*Read September 20, 1950.*]

Radial-Cone and Watersphere elevated tanks are designed to provide for the four fundamental requirements usually specified by most water-works consulting engineers:

1. A reasonably low range between the bottom of capacity and overflow levels, in order to minimize pumping costs and to increase hydraulic efficiency.
2. Strength and security in compliance with the requirements of the 7H.1 Standard Specification for Elevated Steel Water Tanks, Standpipes and Reservoirs, approved by the American Water Works Association, the American Welding Society and the New England Water Works Association.
3. Reducing maintenance costs as far as practicable.
4. A modern attractive appearance, consistent with economical fabrication and erection costs (see Figures 1 and 2).

The Radial-Cone tank bottom plates are curved to form troughs that are portions of a cone. A series of radial girders is supported at the center by the large-diameter riser and the outer ends cantilever over a ring of tubular columns. This design is particularly applicable to capacities in excess of 500,000 gal, as on the larger tanks a self-supporting ellipsoidal bottom would require excessive and uneconomical ranges in head. The tubular columns are hermetically sealed by welding against air or moisture, in order to prevent inside corrosion and to reduce maintenance painting costs.

The Watersphere is a spherical tank, supported on a single cylindrical column with a flared base. The factor of safety of the standard Watersphere designs, to resist overturning from wind loads, is exactly the same as for the alternate type of ellipsoidal tank with the multiple-

*Contracting Engineer, Chicago Bridge & Iron Co., 201 Devonshire St., Boston 10, Mass.

FIG. 1.—RADIAL-CONE TANK

FIG. 2.—WATERSPHERE

post tower braced by rods and struts. An access tube extends through the center of the spherical tank and supports the top section of the ladder to the roof hatch. The steel or wrought-iron riser pipe is attached to supporting brackets and is insulated in freezing climates. Further protection against ice is provided by the air space enclosed between the riser pipe and the cylinder plates. There is a reasonably adequate space inside the flared base section to house small pumping units or other operating equipment. The overflow and inlet connections are made from the inside of the access tube. The encased ladder and locked door in the base section practically prevent children or unauthorized persons from climbing the tank, and thus decrease the danger of liability damage suits for sustained injuries.

Butt-welded joints are used to connect the shell and bottom plates on both the Radial-Cone and Watersphere tanks. A properly made weld should have lasting water-tight and corrosion-resistant properties equal to the rolled plate. The curved roof plates are ¼-inch. This increase by 33% over the 3/16-inch thickness used for conical roofs will result in a more uniform service life.

The smooth butt-welded surfaces are easier to paint than riveted tanks. Observations on existing tanks in the coastal areas of New England appear to justify the conclusion that on gradually curved or flat plates, paint lasts appreciably longer than on the edges of structural shapes and bars, or on rods. When corrosive conditions are especially serious, the Watersphere, which has no small or angular metal sections exposed to the elements, can be expected to require less maintenance than other designs.

Phosphoric-acid pickling is considered by many engineers to provide the best presently-available method of economically preparing tank metal surfaces for painting. In addition to completely removing all mill scale, this process deposits an iron-phosphate surface, which improves the bond for the primer coat of paint. The heavy and thick red-lead mixtures described in the AWWA specifications have resulted in premature failures on tanks exposed to severe freezing conditions. Generally, consulting engineers agree with the recommendations of the tank fabricators that lighter paints be specified.

Standard designs are now available for the following capacities:

Waterspheres—25, 30, 40, 50, 60, 75, 100, 150, 200 and 250 thousand gal.

Radial-Cone tanks—500 and 750 thousand gal and 1, 1½ and 2 mil gal, with ranges in head of 25 to 35 ft.

The saving which results from utilizing standard plans and available dies or jigs in some cases justifies using the next larger standard size, instead of an intermediate special design.

The trend in the construction of water-storage elevated tanks has definitely been toward the assembly of increasingly larger sections on the ground and using improved types of derricks to handle the resultant heavier lifts. The Watersphere has far less component parts than the alternate tanks with multiple posts. As more effective erection procedures are developed, costs might decrease so as to compare favorably, when allowance is made for the superior advantages.

Extra expenditures within reasonable limits are justifiable, to obtain improved appearance on water-storage tanks. This avoids serious decreases in value of property adjacent to the tank site and provides better public relations.

The preparation of specifications for any type of water tank should be entrusted to qualified engineers with wide experience in water-storage problems. The determination of the capacity, height to overflow, range in head, and other details for securing adequate service must be based on engineering studies of the existing system and anticipated future demands. In the appendix of the ? H.1-1948 standard AWWA, AWS and NEWWA tank specifications there is a long list of items to be specified by the tank purchaser or his consulting engineer. The best results are generally obtained when the standard specifications are supplemented by additional data, prepared by a competent water-works engineering organization after comprehensive studies of the conditions involved in the proposed storage project. Neither the standard specification nor available standard designs decrease the necessity for having a qualified engineer to solve the hydraulic problems, in order to obtain the most efficient and economical type of water-storage tank.

The Radial-Cone tank with tubular columns is now the preferred type of storage for larger capacities, as it complies with the previously stated four fundamental requirements for elevated storage. The Watersphere is increasing in popularity and in the future might well become the standard type of elevated tank for the smaller and intermediate capacities.

PROCEEDINGS

April 1951 Meeting

University of Connecticut, Storrs, Conn.

Thursday, April 19, 1951

President Thomas R. Camp in the Chair.

President Camp introduced Melvin Lincoln, President of the Board of Aldermen and Chairman of the Board of Water Commissioners, who welcomed the Association on behalf of the Mayor of Willimantic, Conn.

President Camp then introduced Dr. A. N. Jorgensen, President of the University of Connecticut, who spoke briefly on the problem confronting the man at college, in regard to service in the Armed Forces.

A paper, "Description and Function of the Hydraulic Laboratories of the University of Connecticut", was read by Victor E. Scottron, Professor of Civil Engineering, University of Connecticut, Storrs, Conn.

A paper, "Resumé of the Mansfield Hollow Flood-Control Project", was read by Robert S. Johnson, Resident Engineer, Corps of Engineers, U. S. Army. This paper was followed by a brief question-and-answer period.

A paper, "Problems in Construction of Mansfield Hollow Dam", was read by Vincent Sullivan, Engineer, D. V. Frione & Co., New Haven, Conn.

May 1951 Meeting

Manchester Water Works, Manchester, N. H.

Thursday, May 17, 1951

President Thomas R. Camp in the Chair.

President Camp introduced D. Frank Shea, President of the Board of Water Commissioners, who welcomed the Association on behalf of the Mayor of Manchester. Also, on behalf of Mayor Benoit, Mr. Shea presented President Camp with the key to the city.

A paper, "Administration and Distribution-Maintenance Facilities of Manchester Water Works", was read by Percy A. Shaw, Superintendent and Engineer, Water Works, Manchester, N. H.

A paper, "New Billing Practice at Manchester", was read by James A. Sweeney, Assistant Superintendent, Water Works, Manchester, N. H.

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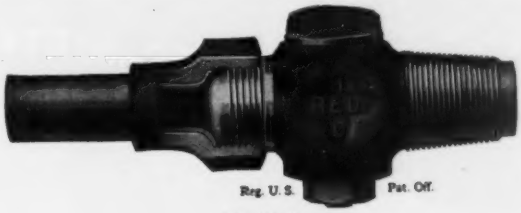

Fig. 438-A

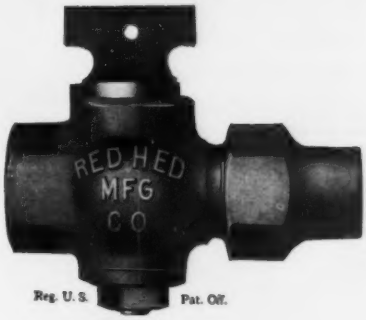

Fig. 408

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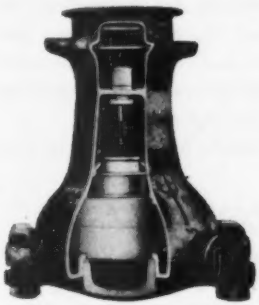

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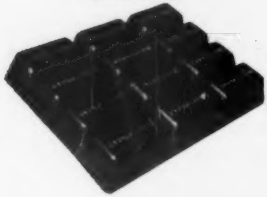

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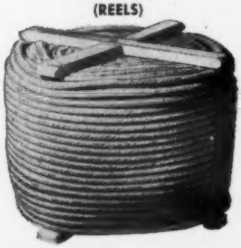

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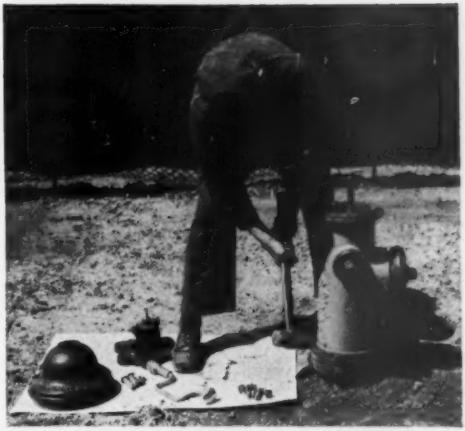

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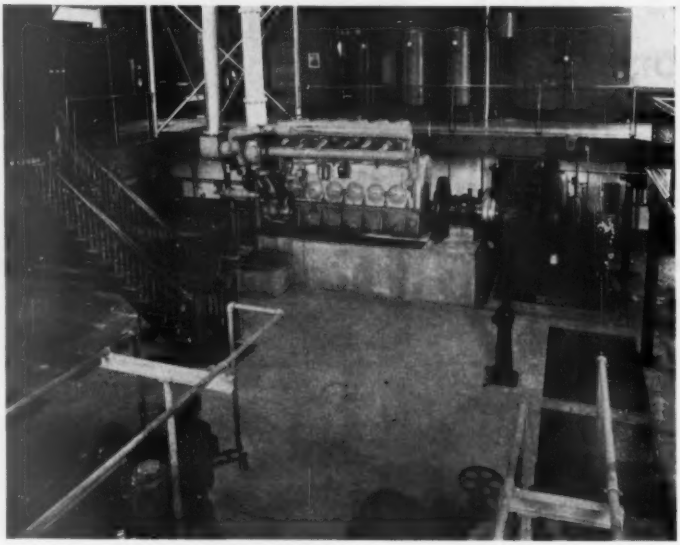

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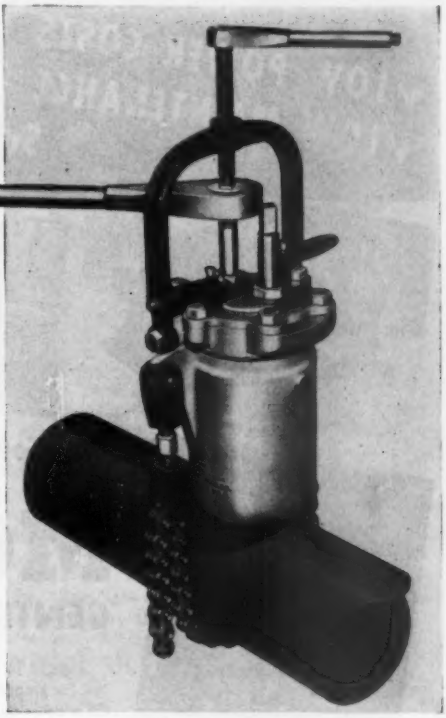

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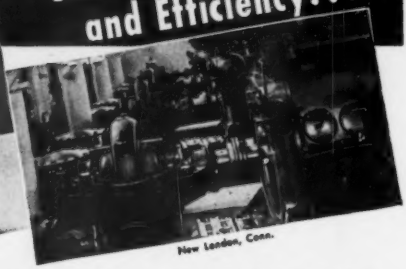
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Valves and Hydrants

Distinctive Features of the EDDY Valves

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Eddy Valve Co.

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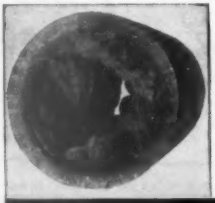

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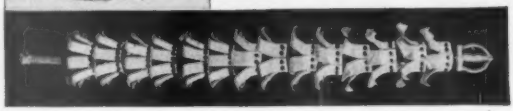

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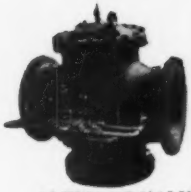

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Maintains desired discharge pressure regardless of change in rate of flow

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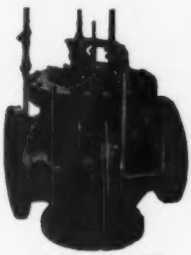
Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



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1. As direct acting

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

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Combination automatic control both directions through the valve.

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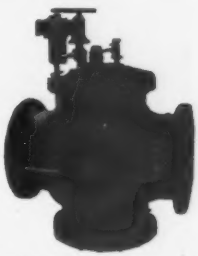

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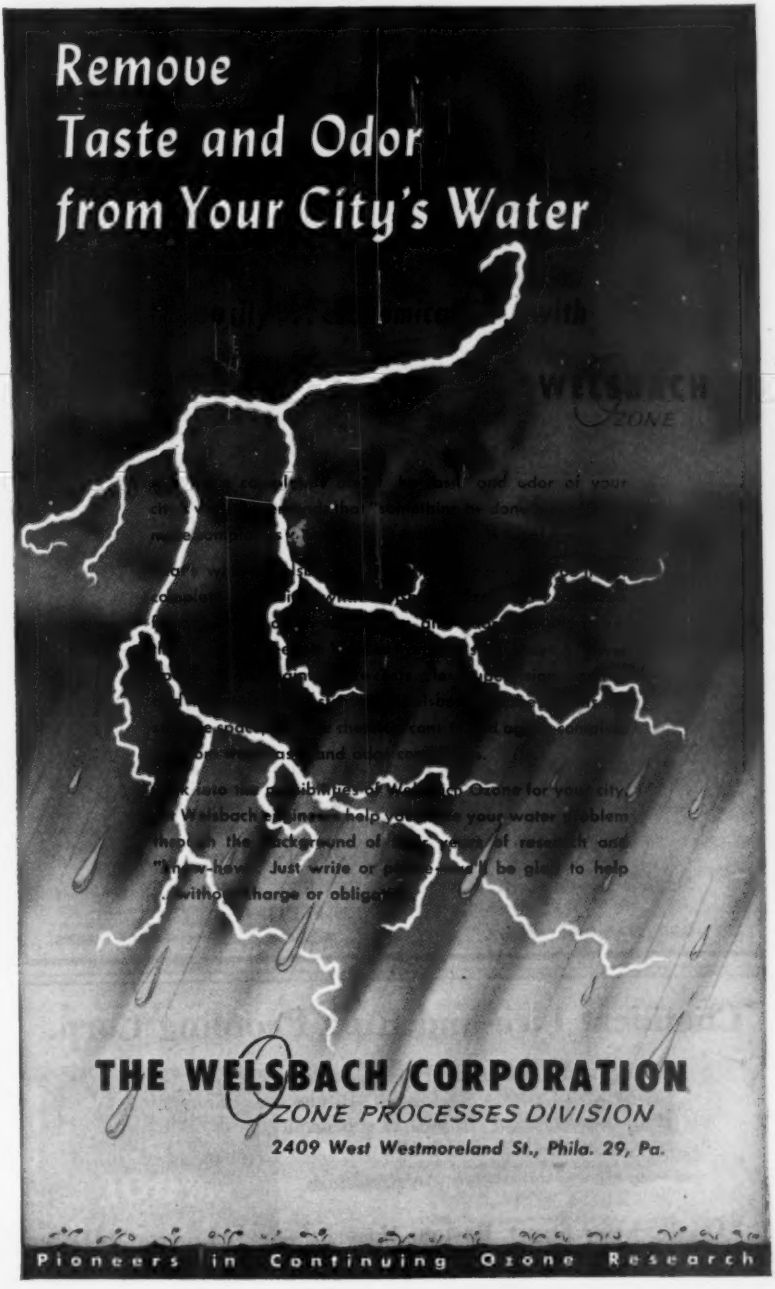
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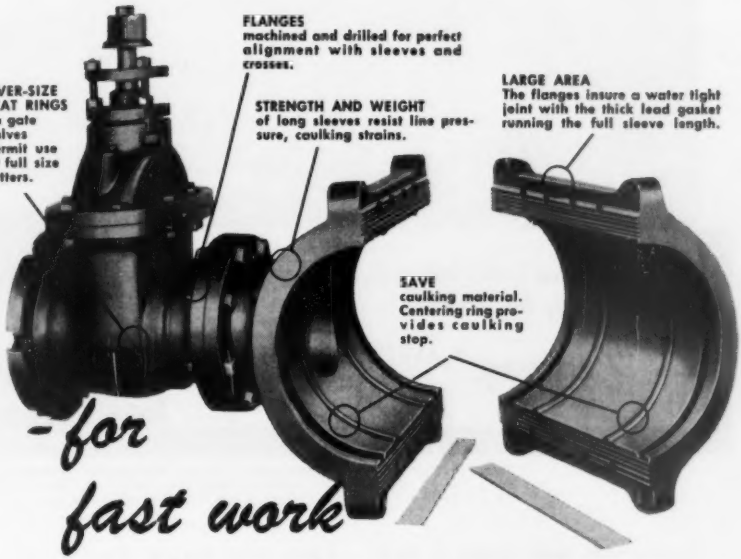
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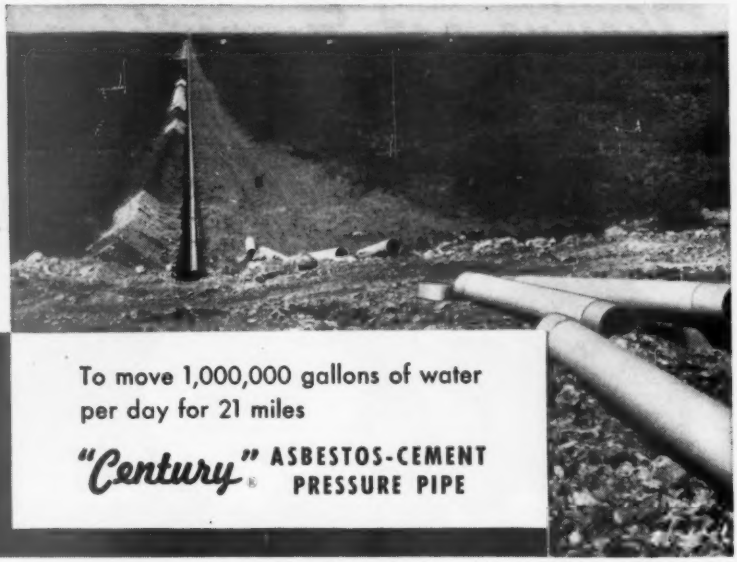

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to aid peak defense production

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